Usability Evaluation for In-Vehicle Systems

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Preface

The work presented in this book was prompted by the need for an evaluation framework that is useful and relevant to the automotive industry. It is often argued that Ergonomics is involved too late in commercial project development processes to have substantive impact on design and usability. In the automotive industry, and specifically in relation to In-Vehicle Information Systems (IVIS), a lack of attention to the issue of usability not only can lead to poor customer satisfaction but can also present a significant risk to safe and efficient driving. This work contributes to the understanding and evaluation of usability in the context of IVIS and is written for students, researchers, designers, and engineers who are involved or interested in the design and evaluation of in-vehicle systems. The book has three key objectives

- Define and understand usability in the context of IVIS. This guides the specification of criteria against which usability can be successfully evaluated.
- Develop a multimethod framework to support designers in the evaluation of IVIS usability. The underlying motivations for the framework are a need for early-stage evaluation to support proactive redesign and a practical and realistic approach that can be used successfully by automotive manufacturers.
- Develop an analytic usability evaluation method that enables useful predictions of task interaction, while accounting for the specific context-of-use of IVIS. The major challenge of this particular context-of-use is the dual-task environment created by interacting with secondary tasks via an IVIS at the same time as driving.

In order to meet these objectives, within the book we have examined how usability evaluation of IVIS can help designers to understand the limitations of current systems in order to develop new concept technologies. The aim of the work is to further readers' understanding of how they can develop more usable systems to enhance the overall driving experience by meeting the needs of the driver for safety, efficiency, and enjoyment. This book is aimed at designers and engineers involved in the development of in-vehicle systems, researchers, and students within the disciplines of Human–Computer Interaction, Ergonomics, and Psychology, and Ergonomics practitioners. We hope that those working in the practical development of in-vehicle systems will make use of the various methods described here in their work on the development and evaluation of future products and will also benefit from the insights into both the theory and empirical findings presented in the book. At the same time, we expect that researchers and students will find the theoretical concepts useful and interesting and that the hypotheses put forward in the book will stimulate further work in this area.

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For Alan

Cath

For Maggie, Josh, and Jem

Neville

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Dr. Catherine Harvey is a research fellow within the Transportation Research Group at the University of Southampton, UK. Catherine was awarded an engineering doctorate (EngD) in 2012 from the University of Southampton. Her research focussed on the usability of in-vehicle interfaces and Ergonomics evaluation methods, and was sponsored by Jaguar Land Rover. Catherine also has a BSc in Ergonomics (Hons) from Loughborough University. She is currently working on the EU Seventh Framework funded project ALICIA (All Condition Operations and Innovative Cockpit Infrastructure), focussing on the evaluation of flight deck display concepts and the pilot–flight deck interaction.

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Prof. Neville Stanton holds the chair in human factors engineering at the University of Southampton. He has published more than 170 peer-reviewed journal papers and 25 books on Human Factors and Ergonomics. In 1998, he was awarded the Institution of Electrical Engineers Divisional Premium Award for work on Engineering Psychology and System Safety. The Institute of Ergonomics and Human Factors awarded him the Otto Edholm medal in 2001, the President's Medal in 2008 and the Sir Frederic Bartlett Medal in 2012 for his original contribution to basic and applied Ergonomics research. In 2007, The Royal Aeronautical Society awarded him the Hodgson Medal and Bronze Award with colleagues for their work on flight deck safety. Prof. Stanton is an editor of the journal *Ergonomics* and on the editorial boards of *Theoretical Issues in Ergonomics Science* and the journal of *Human Factors and Ergonomics in Manufacturing and Service Industries*. Prof. Stanton consults for a wide variety of organisations on topics such as human factors, safety cases, safety culture, risk assessment, human error, product design, warning design, system design, and operation. He has also acted as an expert witness. He is a fellow and Chartered Occupational Psychologist registered with the British Psychological Society, and a Fellow of the Ergonomics Society. He has a BSc (Hons) in Occupational Psychology from the University of Hull, an MPhil in Applied Psychology and a PhD in human factors from Aston University in Birmingham.

Glossary

ACT-R: Adaptive Control of Thought-Rational
ANOVA: Analysis of Variance
CHI: Conference on Human Factors in Computing Systems
CPA: Critical Path Analysis
CPM-GOMS: Cognitive Perceptual Motor—Goals, Operators, Methods and Selection rules
DALI: Driving Activity Load Index
DETR: Department of the Environment, Transport and the Regions
DfT: Department for Transport
EFT: Early Finish Time
EngD: Engineering Doctorate
EPIC: Executive Process—Interactive Control
EST: Early Start Time
GOMS: Goals, Operators, Methods and Selection rules
GPS: Global Positioning System
GSM: Global System for Mobile communications
GUI: Graphical User Interface
HCI: Human–Computer Interaction
HMI: Human–Machine Interface
HTA: Hierarchical Task Analysis
HUD: Head-Up Display
IQR: InterQuartile Range
ISO: International Organization for Standardization
IVIS: In-Vehicle Information System
KLM: Keystroke Level Model
KPI: Key Performance Indicator
LCD: Liquid Crystal Display
LEAF: Learnability, Effectiveness, Attitude, and Flexibility
LFT: Late Finish Time
LST: Late Start Time
MHP: Model Human Processor
MMI: (Audi) MultiMedia Interface
MPH: Miles Per Hour
ms: Milliseconds
NASA-TLX: National Aeronautics and Space Administration—Task Load Index
NMT: Nordic Mobile Telephone network
OEM: Original Equipment Manufacturer
s: Seconds
SD: Standard Deviation
SHERPA: Systematic Human Error Reduction and Prediction Approach
SUS: System Usability Scale

TRL: Transport Research Laboratory
UFOV: Useful Field of View
VCR: Video Cassette Recorder
VDT: Visual Display Terminal
VDU: Visual Display Unit

1 Introduction

THE HISTORY OF IN-VEHICLE INFORMATION PROVISION

From the very early days of the motor car it has been essential for drivers to be able to quickly and easily operate all of the vehicle controls, as well as know the state of the vehicle, which in its most basic form consists of information about speed and fuel level (Damiani et al., 2009). Ergonomics has played a major role in the development of the driver–vehicle interface and evidence for consideration of ease of use can be found as early as 1907, in *A Busy Man's Textbook on Automobiles* (Faurote, 1907):

> Everything has been designed with an eye to accessibility. In all of the four cylinder cars the motor is placed forward under a sheet metal hood in such a position that every part is quickly 'get-a-ble'.… In fact, taken all in all, the general trend of motor car design is to make a machine which will be practical, comfortable and serviceable. (p. 28)

Factors such as accessibility, which are now recognised as central to the Ergonomics purview, were initially considered in relation to the mechanics of the car; however, the need for feedback and information in the vehicle and the vast developments in display technologies over the last century have resulted in dramatic changes to the vehicle's interior. These changes are notable in the design of the dashboard and instrument cluster, and the focus of Ergonomics has shifted accordingly. The introduction of dashboard controls prompted concerns about the driver's physical comfort, particularly as the motor car became more accessible to a wider range of users. An example is given in Figure 1.1, which shows an advertisement from 1969 by the automotive manufacturer General Motors, promoting their appointment of a female 'stylist' to consider the physical reach of women vehicle occupants. Although the approach to vehicle Ergonomics may have evolved somewhat since the early days of the motor vehicle, it is clear that issues such as accessibility and usability have been pertinent for almost as long as people have been driving cars. There is more information available in contemporary vehicles than ever before, which places significant importance on the role of not just physical but also cognitive Ergonomics in vehicle design. In fact, technical evolution has occurred at such a pace that there is potential for it to exceed the capabilities of the driver (Rumar, 1993; Walker et al., 2001; Peacock and Karwowski, 1993) if the in-vehicle interface and the needs of the driver are given insufficient focus during the product development process.

In order to provide some historical context for the book, this chapter documents the development of in-vehicle display and interaction technologies, starting with the first speedometer, introduced in the early 1900s, and finishing with some predictions

FIGURE 1.1 A 1969 advertisement by General Motors highlighting the importance of females' physical reach in vehicle interior design. (Image reproduced courtesy of General Motors.)

for future technological developments within the vehicle. Four timelines were constructed to document the development of in-vehicle systems instrumentation, infotainment, navigation, and comfort; these are each presented alongside a discussion of the technologies. The timelines were based on information from a number of sources, including Azuma et al. (1994), Damiani et al. (2009), Ludvigsen (1997), Newcomb and Spurr (1989), and the websites of individual automotive manufacturers and aftermarket equipment manufacturers.

INSTRUMENTATION

Instrumentation describes the Human–Machine interface (HMI) that connects the driver and the vehicle from the clocks and dials of early motor cars to the digital multi-menu-level displays of today's automobiles (see Figure 1.2). One of the earliest forms of instrumentation in the motor car was a simple speedometer (Newcomb and Spurr, 1989), which was first developed around the turn of the twentieth century by Otto Schulze. Basic instrumentation was attached to the dashboard, which in early motor cars was fixed behind the engine hood to prevent pebbles being dashed from the roadway onto the vehicle occupants. This meant that the instruments were located very low in the vehicle, barely visible to the driver (Ludvigsen, 1997). This lack of accessibility to controls was overcome with the introduction of the instrument panel and integration of instrumentation and controls for the radio and climate appearing between the 1930s and '50s (Ludvigsen, 1997; Newcomb and Spurr, 1989). The provision of a dedicated instrument panel also meant that the driver had full control over the increasing variety of functions appearing in cars during the mid- to late 20th century, including the radio, passenger comfort, and navigation. These in-vehicle functions were controlled by instrument panel dials for many years until

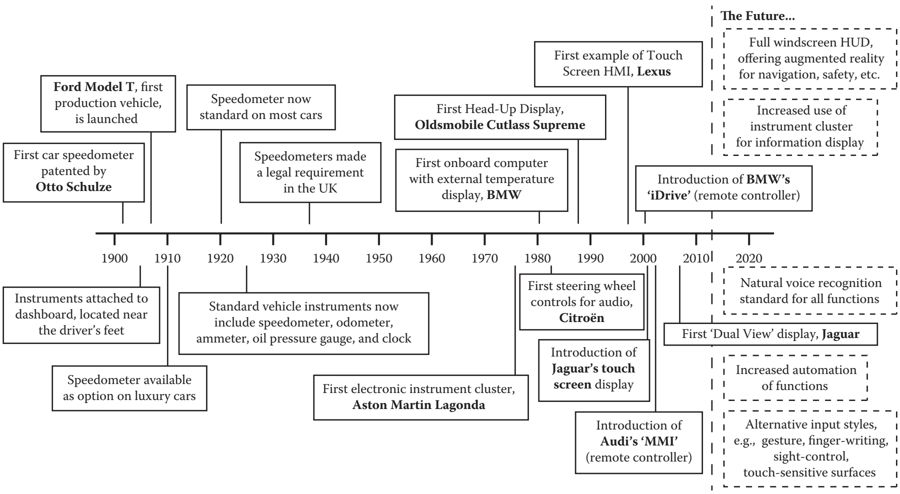

FIGURE 1.2 In-vehicle instrumentation: input and output trends.

FIGURE 1.3 BMW's iDrive IVIS. (Author's own photographs.)

the development and widespread introduction of In-Vehicle Information Systems (IVIS), which integrated the controls for many in-vehicle functions into a single screen-based device. One of the earliest examples of this new vehicle interaction style was Lexus's touch screen system, introduced in 1997. This was closely followed by other touch screen devices (e.g., Jaguar) and by an alternative remote control interaction style, the most well-known being BMW's iDrive system, introduced in 2001 (see Figure 1.3). These IVIS changed the appearance of traditional vehicle dashboards by reducing the number of separate hard dials. This development also increased the capacity for functionality in the vehicle, and today's car offers infinitely more infotainment, navigation, communication, and comfort options than the early motor vehicle. A recent example of a touch screen IVIS from Jaguar Cars is shown in Figure 1.4; this displays a single screen-based interface located in the centre console, which integrates many secondary vehicle functions into a single system. Further advances in display technology for the vehicle have included the Head-Up Display (HUD), which was first introduced in cars in 1988 by the vehicle manufacturer Oldsmobile and is predominately used for displaying basic information such as speed, parking monitor displays (including the first 360-degree Around-View system by Infiniti [2010]), and 'dual view' screens, introduced in the vehicle by Jaguar in 2007 (Jaguar Cars Limited, 2011).

FIGURE 1.4 An example of a modern touch screen IVIS as seen in Jaguar vehicles. (Image reproduced courtesy of Jaguar Cars.)

INFOTAINMENT

Infotainment refers to the provision of information, entertainment, and communication functions within the vehicle; the development timeline is shown in Figure 1.5. The earliest attempts at providing radio to the driver consisted of a radio receiver connected to an amplifier and loud speaker, which was mounted on the side of a vehicle. An example, the Marconiphone, is shown connected to the running board of a car in Figure 1.6. Radio was the first source of entertainment to be integrated into the vehicle, with one of the earliest examples being the Galvin Manufacturing Company's Motorola in 1930, which was specifically designed as a car radio (Motorola Solutions, 2012). This proved a popular addition, and shortly afterwards many vehicle manufacturers began to fit radio wiring in their vehicles as standard (Ludvigsen, 1997). Building on the popularity of the in-car radio, manufacturers started to introduce recorded media into the vehicle, beginning with 45-rpm records, although these were unable to successfully withstand the vibrations from the road surface (Ludvigsen, 1997), and were soon replaced when Philips produced the first standard cassette player in the late 1960s (Koninklijke Philips Electronics, 2012). In-car entertainment kept pace with developments in prerecorded media, with the first vehicle CD player developed in the mid-80s by Pioneer (Pioneer Europe, 2012), followed by MP3 capability in the late 1990s (Empeg, 2012). More recently, video capabilities have been added to the vehicle, with the first in-car Blu-ray players introduced within the last 5 years. The addition of visual entertainment could be perceived as a worrying trend in terms of distraction and driver safety; however, manufacturers have gone some way to acknowledge these issues, introducing technologies such as Jaguar's Dual-View screen, which displays different images depending on the viewing angle, thereby restricting the view of moving images to the passenger only (Jaguar Cars Limited, 2011).

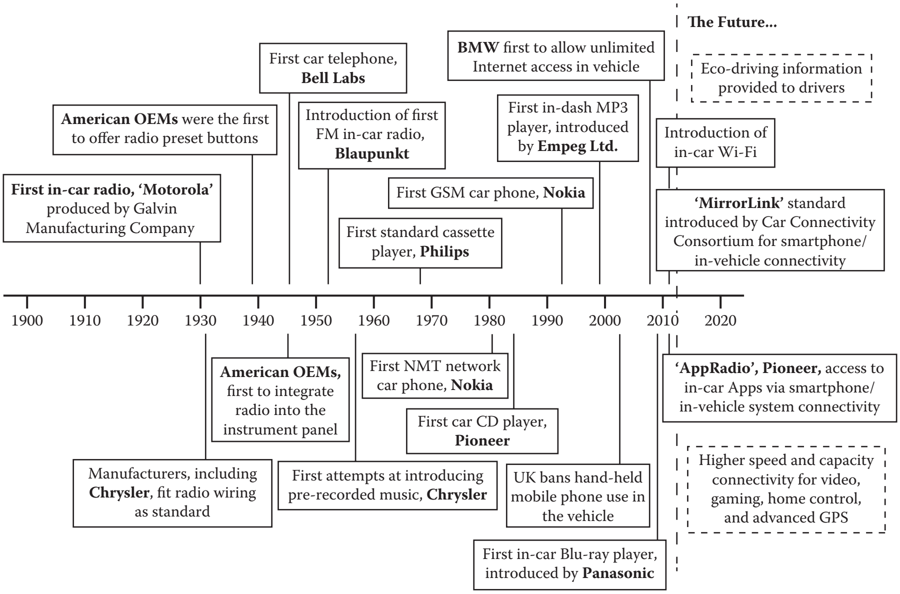

FIGURE 1.5 In-vehicle infotainment trends.

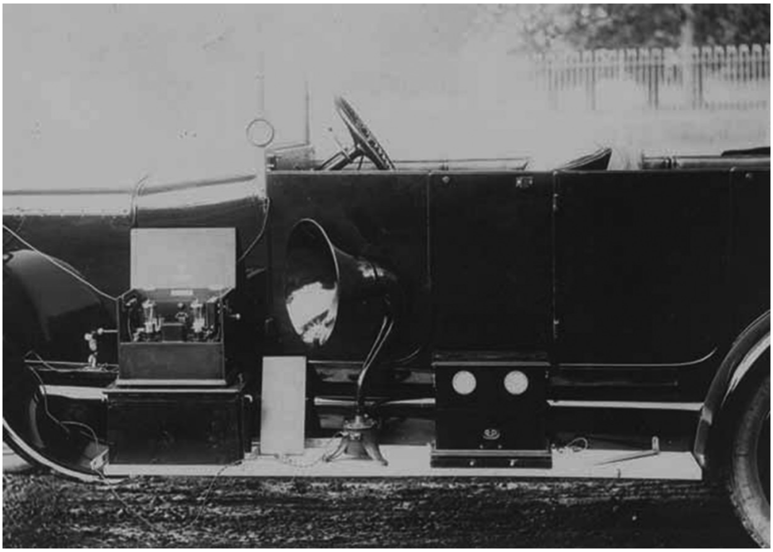

FIGURE 1.6 Marconiphone V2 wireless receiver, mounted on the running board of a car. (Image reproduced courtesy of Telent Limited.)

Another aspect of infotainment functionality, communication, was an important feature in the development of the motor car, with the first car telephone pioneered by Bell Labs in 1946 (AT&T, 2012). Further improvements in car phone technology was driven by the development of mobile communication networks: Nokia introduced the first car phones for the first fully automatic cell phone system, the Nordic Mobile Telephone (NMT) network, established in 1981 (Nokia, 2009; Staunstrup, 2012). This was followed by the Global System for Mobile Communications (GSM) network, created in the early 1990s, which was accompanied by the first GSM car phone, introduced by Nokia in 1993 (Nokia, 2009). Still keeping relative pace with the technological development of communication technologies, automotive manufacturers allowed Internet access in the car in the late 2000s. Today, many drivers are able to access the web via a smartphone connected to the vehicle, and there are even 'apps' designed specifically for in-vehicle use.

NAVIGATION

Vehicle navigation was also an area of much interest from the very early days of motor vehicle (see Figure 1.7). The Jones Live-Map, shown in Figure 1.8, is the earliest example of a navigation system. Developed in 1909, it used a cable connecting the car's front wheels to turn a circular map indicating the vehicle's position along a route (Moran, 2009). Development in this area, however, did not really flourish until the 1980s, when Honda introduced the Electro Gyrocator, which was the first gyroscopic navigation system, incorporating a mechanism which scrolled static maps through a display to indicate position (Honda Motor Company, 2012). The first Global Positioning System (GPS) navigation device, Toyota's Crown system, was introduced in 1988 (Azuma et al., 1994), followed shortly after by the first aftermarket navigation system, developed by Pioneer in 1991 (Pioneer Europe, 2012).

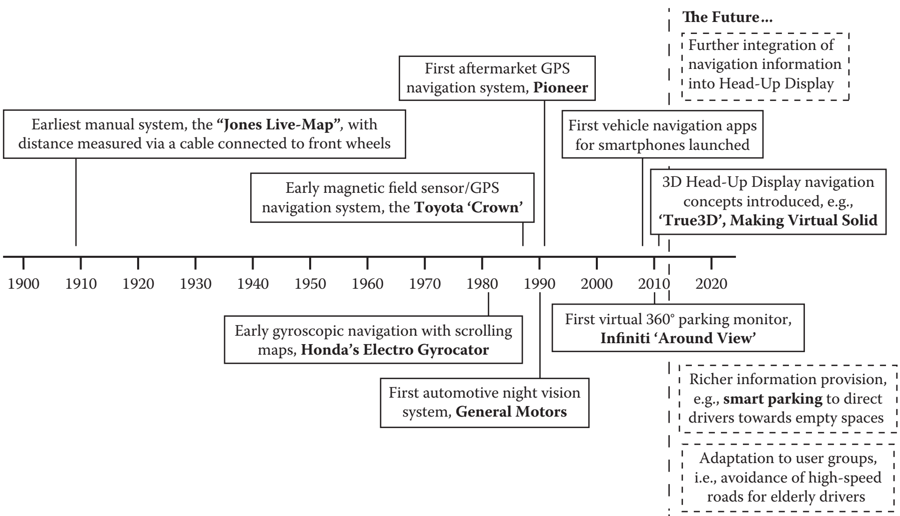

FIGURE 1.7 In-vehicle navigation system trends.

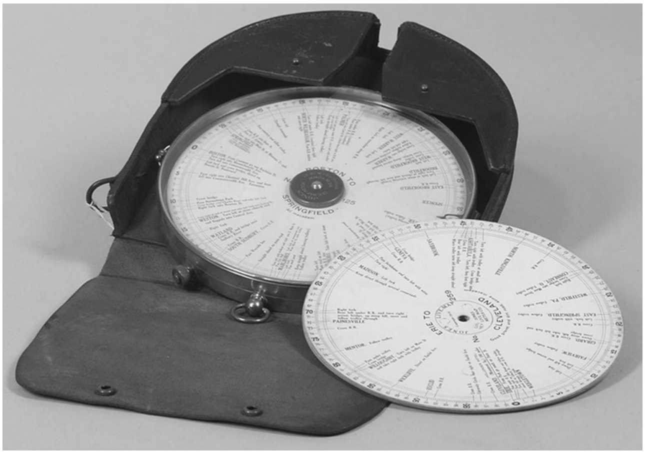

FIGURE 1.8 The Jones Live-Map, one of the earliest automobile navigation systems. (Image reproduced courtesy of Skinner Inc., www.skinnerinc.com.)

More recently, there has been a huge increase in sales of aftermarket, or nomadic, navigation devices (Stevens, 2012), most offering a touch-screen interface; however, with the continuous improvements in smartphone technology, for instance, screen size and resolution, and the increasing availability of navigation apps tailored to the car, it is likely that aftermarket navigation-only devices will experience a decline in popularity over the coming years (Stevens, 2012). Supplementary navigation-related functions also continue to emerge, and recent years have seen the introduction of night-vision systems, parking monitors, and 3D route displays integrated into a HUD.

COMFORT

The early automobile was open to the elements, a feature which was, in fact, seen to increase the pleasure of driving a car (Ludvigsen, 1997). In these very early days, the driver and passengers had to adjust themselves to the car (Ludvigsen,1997); however, as the motor car developed, more attention was paid to comfort, initially of rear-seat occupants, followed later by the driver. The first front- and rear-compartment heating systems began to appear in the early twentieth century (see Figure 1.9), with the first heating system developed by Ford in 1933 and the first air conditioning system produced by the Packard Motor Company in 1939 (Ludvigsen, 1997). Modern automobiles now adjust themselves to the driver, providing heating and cooling to different parts of the vehicle, automatically controlled or activated by the driver via the IVIS or dashboard dials.

FUTURE PREDICTIONS

Based on the rate of recent advances in in-vehicle technology it is very likely that development will continue at pace with the introduction of many more functions and devices into the vehicle. In an attempt to forecast some of the advances in IVIS

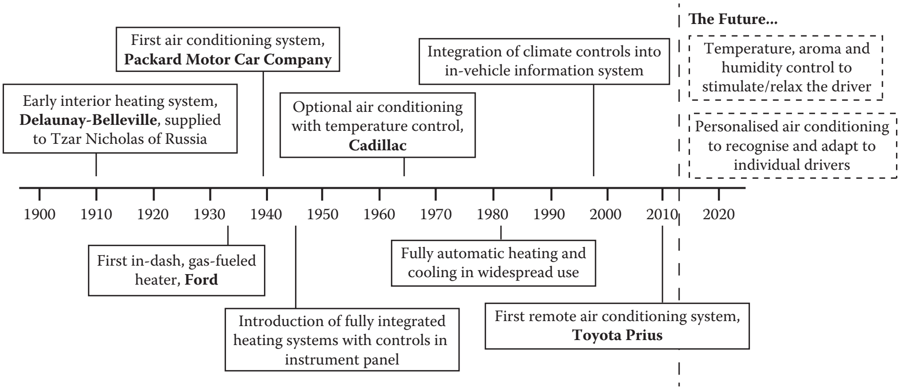

FIGURE 1.9 In-vehicle comfort control trends.

expected over the next decade, predictions for future in-vehicle technology have been incorporated into the timelines. In terms of instrumentation and interaction styles, it is likely that the expected improvements in technology will allow natural voice recognition to become an important component of vehicle feedback and control in the near future. Other alternative input styles are also likely to be seen more widely in cars, including gesture recognition, full HUD, and augmented reality applications. Cars move increasingly toward a 'glass cockpit/dashboard' concept as predicted by Walker et al. (2001), with more and more instruments moving to digital displays and the opportunities for driver-customization of displays looking likely. Automation is currently a very popular topic in vehicle research (see, for example, Heide and Henning, 2006; Jamson et al., 2011; Khan et al., 2012; Stanton et al., 2007b; Stanton et al., 2011; Rudin-Brown, 2010; Young and Stanton, 2007), and increasing levels of automation may actually reduce the number of functions with which the driver needs to interact. However, this is not expected to reduce the variety of interaction styles introduced by original equipment manufacturers (OEMs), as there appears to be an ever-intensifying drive toward novel interaction technologies. Over the last decade the need for adaptive information presentation has been acknowledged by researchers and automotive manufacturers (see Amditis et al., 2006; Hoedemaeker and Neerincx, 2007; Piechulla et al., 2003; Rudin-Brown, 2010; Sarter, 2006; Walker et al., 2001). Adaptive in-vehicle systems assess the state of the driver (e.g., awareness and fatigue) and provide real-time information or warnings to assist the driver or restrict access to particular functions in situations of high workload. The first examples of adaptive information presentation are now being seen in production vehicles, with Lexus introducing the world's first Advanced Pre-Collision System, which uses an infrared camera to monitor the direction of the driver's face. If the driver is facing away, and the system detects a potential obstacle in the vehicle's path, the car can automatically apply the brakes and retract the front seatbelts (Lexus, 2012). Other vehicle manufacturers, including Volkswagen and Daimler, have recently introduced fatigue monitoring systems that produce auditory and visual alerts when drowsiness is detected (Daimler, 2012; Volkswagen, 2012). There is also currently much attention on eco-driving (Birrell et al., 2011; Damiani et al., 2009; Flemming et al.,

2008; Young et al., 2011b), and with more hybrid and electric vehicle entering the market, in-vehicle information provision will need to account for differences in driving styles and vehicle operation brought about by these developments (Young et al., 2011b). Focus on the comfort of the driver is likely to continue (Damiani et al., 2009), and technologies that enable the car to adapt the internal thermal environment to the current state of the driver are expected in the near future. Increasing levels of connectivity, via high-speed, wide-ranging Internet access and the use of portable devices such as smartphones, means that vehicle users now expect to be able to connect to a massive amount of information whilst driving (Damiani et al., 2009). Recent initiatives such as MirrorLink (Car Connectivity Consortium, 2011), which is an open-industry standard for car-centric connectivity solutions, seek to increase the connectivity between portable devices and in-vehicle systems, and there is likely to be an increase in the number of in-vehicle devices that offer this seamless integration to people's smartphones and personal computers. This proliferation of in-vehicle technology is intended to enhance the driving experience; however, it is not without its disadvantages, as the higher the demand for attention inside the vehicle, the less attention is available for eyes-out monitoring of the road. This poses a considerable Ergonomics challenge for automotive manufacturers and researchers into the future.

ERGONOMICS CHALLENGES OF IN-VEHICLE INFORMATION SYSTEMS (IVIS)

Over the last decade, IVIS have become established as a standard technology in many road vehicles. Since the introduction of these multifunctional, menu-based systems in vehicles around the beginning of the 21st century, they have attracted much attention, and this has not always been positive. This has brought the concept of usability into sharp focus. Ten years ago the main focus of attention was on how much technology could be brought into vehicles. Today, the challenge is balancing the ever-increasing demand for technology with the users' needs, not only for form and function, but also for a usable HMI.

In 2011 there were 203,950 reported road casualties in Great Britain, although the Department for Transport (DfT) estimated the actual number to be nearer to seven hundred thousand every year as many accidents, particularly those involving non-fatal casualties, are not reported to the police (Department for Transport, 2012). Distraction in the vehicle was a contributory factor in almost three thousand of the reported road accidents in 2010 (Department for Transport, 2011a). This amounted to two per cent of all reported accidents; however, the World Health Organization (2011) suggested that this is likely to be an underestimate because of the difficulty in identifying distraction related incidents. In the United States, 18% of injury crashes in 2010 were described as distraction-affected (National Highway Traffic Safety Administration, 2012). Cars are now constructed to make driving safer than ever, but the risk from performing secondary tasks within the vehicle remains a significant threat to driver safety (Regan et al., 2009; Young et al., 2008). Secondary driving tasks are not directly involved in driving (Hedlund et al., 2006) and relate to the control of infotainment, comfort, navigation and communication functions. Primary

driving tasks include steering, braking, controlling speed, manoeuvring in traffic, navigating to a destination and scanning for hazards (Hedlund et al., 2006), with the aim of maintaining safe control of the vehicle (Lansdown, 2000). Interaction with secondary tasks is a potential cause of in-vehicle distractions because it can increase the demands on the driver's visual, cognitive, auditory, and physical resources and this may result in a reduction in the driver's attention to the primary driving task (Burnett and Porter, 2001; GuJi and Jin, 2010; Hedlund et al., 2006; Lee et al., 2009; Matthews et al., 2001; Young and Stanton, 2002; Hancock et al., 2009b).

Traditionally, secondary functions were operated via a series of hard switches mounted on the vehicle's dashboard; see Figure 1.10. Today, in the premium sector, and increasingly with volume brands, these functions are integrated into a single menu-based system, for example, the rotary controller (Figure 1.3) and the touch screen (Figure 1.4), with only the most high-frequency and high-importance controls left as hard switches. The IVIS make use of a screen-based interface, which reduces the cluttered appearance of the dashboard and is considered to be an aesthetically superior solution to the traditional layout (Fleischmann, 2007). The ease with which a driver can interact with an IVIS is determined by the HMI because this influences a driver's ability to input information to the IVIS, to receive and understand information outputs, and to monitor the state of the system. As a result of the demand for enhanced in-vehicle functionality, IVIS complexity is increasing at a rate which is, in some cases, exceeding human capabilities: this is likely to result in an increase in driver distraction (Walker et al., 2001). This problem was exemplified by the BMW iDrive, released in 2000 (see Figure 1.3). Despite other similar systems by Audi and Mercedes to name but a few coming under fire for lack of efficiency and excessive menu complexity (Cunningham, 2007), it was BMW's rotary-controlled IVIS, which received the most high-profile criticism from the media and users alike (Cobb, 2002; Farago, 2002). Accusations that the iDrive lacked learnability (Cunningham, 2007), introduced redundancy on the dashboard, and attempted to incorporate vastly more functions into the vehicle than the driver would ever need (Cobb, 2002) pushed the issue of usability to the wider attention of the public. As the iDrive attracted increasing notoriety, reports like that by Farago (2002), which claimed that the iDrive was not 'a new way to drive' as BMW intended but rather a 'new way to die', served to fuel the attention on the issues of driver distraction and safety. This prompted much research into the interaction between the driver and IVIS and the effects of this on distraction (for an overview see Beirness et al., 2002; Carsten, 2004; Lansdown et al., 2004a, Lee et al., 2009; Young et al., 2003). With the ever-evolving face of IVIS, the transforming role of the driver from operator to monitor with increasing automation and the changes in driver demographics expected over the next decades, this research is still in full flow.

Increased complexity of IVIS interactions has been shown to be linked to poor driving performance; for example, Horrey (2011) reported that more complex tasks tend to result in longer glances away from the road than easier tasks, resulting in a lack of awareness of the road environment. This illustrates a situation in which the demands of an IVIS task exceed the capabilities of the driver, resulting in the degradation of the driver's visual attention to the road. The design of new in-vehicle technologies must account for this mismatch between IVIS complexity and the driver's

FIGURE 1.10 Traditional switch-based layout of the vehicle dashboard. (Author's own photograph.)

capabilities; otherwise, the benefits offered by the growth in in-vehicle functionality will be outweighed by the associated rise in distraction and consequent risk to safety (Hedlund et al., 2006; Hancock et al., 2009b). In its Strategic Framework for Road Safety, the DfT identified the potential for new technology to cause driver distraction as an important factor for the future of road safety (Department for Transport, 2011b). The DfT acknowledged that whilst the continued development of in-vehicle technologies is expected, there is a need to encourage manufacturers towards a solution that enables these technologies to be used safely within the car (Department for Transport, 2011b). This book aims to directly address these issues.

ERGONOMICS, HUMAN COMPUTER INTERACTION (HCI), AND USABILITY

Ergonomics can be defined as 'the application of scientific information concerning humans to the design of objects, systems, and environments for human use' (Whitfield and Langford, 2001). Ergonomics is 'an applied, multidisciplinary subject' (Buckle, 2011) that uses analysis and understanding to optimize design, 'augmenting and supporting human endeavour' (Lindgaard, 2009). Above all, Ergonomics focusses on identifying the needs of the user and designing to address these needs (Caple, 2010). The application of Ergonomics transcends disciplines, making products more usable, workplaces safer and transport systems more efficient. It can contribute to solving today's big issues, such as supporting our aging population and reducing the risk of major infection outbreaks in our hospitals. Ergonomics can offer insights into the causes and consequences of major incidents, from accidents like the Chernobyl

Nuclear Power Plant catastrophe (e.g., Munipov, 1992), the 1999 Ladbroke Grove rail crash (e.g., Stanton and Baber, 2008; Stanton and Walker, 2011) and the Kegworth air disaster (e.g., Griffin et al., 2010; Plant and Stanton, 2012), to the planning and implementation of large-scale public events such as the Olympic Games (e.g., Franks et al., 1983) and relief efforts like that which followed the 2010 Haiti earthquake (e.g., Hutchins, 2011). It can be applied to investigate a hugely diverse, and sometimes surprising, range of issues, from the most optimal search strategies of football goal-keepers facing a penalty shoot-out (Savelsbergh et al., 2005) to the effects of expertise on the performance of crime scene investigators (Baber and Butler, 2012). A recent paper promoting a strategy for the discipline, described Ergonomics as having great potential to optimise the performance and well-being of humans interacting with any designed artefacts, from single products to entire systems and environments (Dul et al., 2012). The authors described developments in the external world that are changing the way humans interact with their environment; these included the introduction of technology with capabilities that far exceed those of the human, significant changes in the way humans interact with technology, and advances in the type of information transferred via new telecommunications and media (Dul et al., 2012). These changes will continue to have a huge impact on the way humans experience the world, including work, travel, healthcare, education, entertainment, and other activities.

The way in which information is transferred to human users via the products they use and the systems they are part of is the focus of HCI research, which could be considered a subdiscipline of Ergonomics. In fact, there has always been a close link between Ergonomics and HCI, for example, in 1982 the first Conference on Human Factors in Computing Systems (CHI) was cosponsored by the Human Factors Society (Grudin, 2009). The emergence of HCI as a discipline coincided with the shift from the use of computers purely in the workplace to the rise of personal computing in the early 1980s (Carroll, 2010; Dix, 2010; Noyes, 2009). The introduction of HCI is attributed to Brian Shackel (see Shackel, 1959) in the late 1950s (Dix, 2010; Dillon, 2009), although it was fully established later with the founding of HCI conferences, including INTERACT and CHI, in the early 1980s (Dix, 2010). Since its conception, HCI has expanded rapidly, commensurate with the vast developments in interactive technologies, the rapid growth in the number of people using computers (Hartson, 1998) and the accompanying expansion and diversification of the concept of usability (Carroll, 2010). Although when it was first introduced, HCI only referred to desktop computing, today the term encompasses a much wider field of study that centres on the relationships and activities between humans and the diverse range of devices with which they interact (Dix, 2010; Carrol, 2010). In this book HCI is used to refer to the computers inside vehicles, which control a wide spectrum of functions ranging from entertainment to climate control, and the emergent behaviour of drivers using these ‘computers’.

Usability is a central concept in HCI, and much of the early work on usability evaluation was borne of the frustrations on the part of HCI researchers that usability issues were only ever considered toward the end of the product development process (Lindgaard, 2009). Usability represents an area in which HCI professionals could have a large influence on the design of new technologies (Dillon, 2009); however, for this to be successful, design for usability needs to be supported by effective methods

and tools. Dix (2010) differentiated between the goals of usability (i.e., practice, leading to an improved product) and the goals of HCI research (i.e., scientific theory, leading to new understanding), although he also stated that these goals should be interlinked because 'effective design will be based on a thorough understanding of the context and technology' (Dix, 2010; p. 15). The integration of science and practice has been described as a 'significant achievement' of HCI (Carroll, 2010) and is also a key feature of the Ergonomics discipline (Buckle, 2011), although Buckle differed slightly in his description of it as an 'ongoing tension between current practice and … research' (p. 2), which relies on the effective exchange of information between researchers and practitioners. Other authors have echoed Buckle's concerns; for example, Caple (2010) suggested that the beneficiaries of much of the Ergonomics research do not actually read the academic journals or attend the conferences in which it is published. Consequently, it appears that although the combination of both science and practice is seen as very positive for a well-balanced discipline (Buckle, 2011), there is a real need for the correct balance to be struck and to encourage and support effective communication between the researchers generating the knowledge, the practitioners applying this knowledge and also, perhaps most important, the users interacting with the end products. In this vein, Meister (1992) recommended that although Ergonomics is dependent upon research, this research 'must be geared to the … needs of the design engineer'. Caple (2010) summarised these requirements by proposing a holistic approach, engaging a wide range of stakeholders, in order to sustain the effectiveness of Ergonomics interventions. The integration of usability goals with the goals of HCI research, realised by an interlinking of theory and practice, is also a central theme pursued in this book. The knowledge generated via review, analysis and experiment is presented in an accessible way for automotive manufacturers and designers to use to support practical product development.

Long (2010) stressed the importance of a consensus of a particular design problem before successful evaluation can take place. Without this, he suggested, researchers are unable to validate or compare their findings. The concept of usability is an example of where a detailed definition is required before evaluation can take place, although this is a concept which is not straightforward to describe, despite numerous attempts by a number of authors (see Bevan, 1991; Nielsen, 1993; Norman, 1983; Shackel, 1986; Shneiderman, 1992). Although usability is widely regarded to be 'a crucial driving force for user interface design and evaluation' (Hartson, 1998), it is difficult to create a universal definition because it is so dependent on the specific aspects of the context within which particular devices and products are used. In this book, significant attempts at defining usability, along with the issue of context, which has made this such a difficult task, are discussed. As advocated by Long (2010), a conceptualisation for a usable IVIS is presented in the early chapters of this book in the form of usability criteria. This work forms the foundation for a comprehensive evaluation process targeted at understanding and improving the usability of IVIS.

USABILITY EVALUATION

The concept of usability is constantly evolving, and Carroll (2010) suggested that it will continue to do so 'as our ability to reach further toward it improves' (p. 11).

The increasing richness of the concept also means that the evaluation of usability is becoming ever more complex and problematic (Carroll, 2010). HCI has been described as a 'meta-discipline' (Carroll, 2010), which has always drawn from other fields, including Ergonomics, cognitive psychology, behavioural psychology, psychometrics, systems engineering, and computer science (Hartson, 1998), and this list continues to diversify as usability subsumes wider qualities such as aesthetics, well-being, quality of life and creativity (Carroll, 2010; Hancock and Drury, 2011; Lindgaard, 2009). The context within which products are being used also continues to evolve (Lindgaard, 2009); therefore, researchers need better means of predicting these situations and the associated emergent behaviours. Hartson (1998) reported a general agreement in the literature that interaction development needs to involve usability evaluation: this reiterates the requirement for an integrated and iterative process of design–evaluation–redesign, which is the model presented in this book.

Dix (2010) described evaluation as 'central' to HCI; however, the real or perceived costs associated with evaluation often prevent it from being successfully and sufficiently implemented in the product development process (Hartson, 1998). In reality, usability engineering often does not increase product development costs as much as people may think and the benefits of good usability in the final product will almost always outweigh the costs of the process (Hartson, 1998). A key aim for enforcing this message to manufacturers is to present them with appropriate tools to support usability evaluation, particularly at stages in the process when maximum benefits to the final product will be realised, i.e., early in concept development.

One of the most significant developments in the evaluation of HCI has been the modelling work of Card et al. (1983), which began with the Model Human Processor (MHP) and the Goals, Operators, Methods, and Selection Rules (GOMS) model, and was one of the first applications of cognitive theory in HCI (Carroll, 2010; Hartson, 1998). This work has since been added to with significant contributions in the form of EPIC (Executive Process Interactive Control; Kieras and Meyer, 1997), ACT-R (Atomic Components of Thought; Anderson and Lebiere, 1998) and CPA (Critical Path Analysis; Lockyer, 1984). Rather than measuring human–computer interaction as it occurs, modelling predicts the success of the interaction based purely on prior information about human processing, the tasks that would be performed, and the environment in which they would be performed. Meister (1992) stressed the importance in Ergonomics of being able to *predict* human performance, and it provides a solution to the problems commonly associated with usability testing because it is relative inexpensive to carry out and can be applied at an early stage in the product development process. In this book, a modelling approach is investigated as part of a toolkit of measures for evaluating the usability of IVIS.

BOOK OUTLINE

The book is organised in nine chapters, starting with an introduction which describes the background to the work and outlines the main research objectives (Chapter 1). An overview of the remaining chapters follow.

Chapter 2: Context-of-Use as a Factor in Determining the Usability of In-Vehicle Information Systems. In recent years, the issue of usability of IVIS has received

growing attention. This is commensurate with the increase in functionality of these devices, which has been accompanied by the introduction of various new interfaces to facilitate the user–device interaction. The complexity and diversity of the driving task presents a unique challenge in defining usability: user interaction with IVIS creates a 'dual task' scenario, in which conflicts can arise between primary and secondary driving tasks. This, and the safety-critical nature of driving, must be accounted for in defining and evaluating the usability of IVIS. It is evident that defining usability depends on the context-of-use of the device in question. The aim of the work presented in Chapter 2 was therefore to define usability for IVIS by selecting a set of criteria to describe the various factors that contribute to usability in this specific context-of-use and to define Key Performance Indicators (KPIs) against which usability could be measured.

Chapter 3: In-Vehicle Information Systems to Meet the Needs of Drivers. IVIS integrate most of the secondary functions available within vehicles. These secondary functions are aimed at enhancing the driving experience. To successfully design and evaluate the performance of these systems, a thorough understanding of the task, user, and system, and their interactions within a particular context-of-use, is required. Chapter 3 presents a review of these three variables in the context of IVIS, which aims to enhance understanding of the factors that affect system performance. An iterative process for modelling system performance for the task–user–system interaction is also illustrated. This will support designers and evaluators of IVIS in making predictions about system performance and designing systems that meet a set of criteria for usable IVIS.

Chapter 4: A Usability Evaluation Framework for In-Vehicle Information Systems. Usability must be defined specifically for the context-of-use of the particular system under investigation. This specific context-of-use should also be used to guide the definition of specific usability criteria and the selection of appropriate evaluation methods. There are four principles that can guide the selection of evaluation methods, relating to the information required in the evaluation, the stage at which to apply methods, the resources required, and the people involved, for instance, the skills of the analysts and whether or not representative users are tested. Chapter 4 presents a flowchart to guide the selection of appropriate methods for the evaluation of usability in the context of IVIS. This flowchart was used to identify a set of analytic and empirical methods which are suitable for IVIS evaluation. Each of these methods has been described in terms of the four method selection principles.

Chapter 5: The Trade-Off between Context and Objectivity in an Analytic Evaluation of In-Vehicle Interfaces. Chapter 5 presents a case study to explore an analytic approach to the evaluation of IVIS usability, aimed at an early stage in product development with low demand on resources. Five methods were selected: Hierarchical Task Analysis (HTA), Multimodal Critical Path Analysis (CPA), Systematic Human Error Reduction and Prediction Approach (SHERPA), Heuristic Analysis, and Layout Analysis. The methods were applied in an evaluation of two IVIS interfaces: a touch screen and a remote controller. The findings showed that there was a trade-off between the objectivity of a method and consideration of the context of use; this has implications for the usefulness of analytic evaluation. An extension

to the CPA method is proposed as a solution to enable more objective comparisons of IVIS, whilst accounting for context in terms of the dual-task driving environment.

Chapter 6: To Twist or Poke? A Method for Identifying Usability Issues with Direct and Indirect Input Devices for Control of In-Vehicle Information Systems. IVIS can be controlled by the user via direct or indirect input devices. In order to develop the next generation of usable IVIS, designers need to be able to evaluate and understand the usability issues associated with these two input types. The aim of the study presented in Chapter 6 was to investigate the effectiveness of a set of empirical usability evaluation methods for identifying important usability issues and distinguishing between the IVIS input devices. A number of usability issues were identified and their causal factors have been explored. These were related to the input type, the structure of the menu/tasks, and hardware issues. In particular, the translation between inputs and on-screen actions and a lack of visual feedback for menu navigation resulted in lower levels of usability for the indirect device. This information will be useful in informing the design of new IVIS, with improved usability.

Chapter 7: Modelling the Hare and the Tortoise: Predicting IVIS Task Times for Fast, Middle and Slow Person Performance using Multimodal Critical Path Analysis. Analytic models can enable predictions about important aspects of the usability of IVIS to be made at an early stage of the product development process. Task times provide a quantitative measure of user performance and are therefore important in the evaluation of IVIS usability. In this study CPA was used to model IVIS task times in a stationary vehicle and the technique was extended to produce predictions for 'slowperson' and 'fastperson' performance, as well as average user ('middleperson') performance. The CPA-predicted task times were compared to task times recorded in an empirical simulator study of IVIS interaction and the predicted times were, on average, within acceptable precision limits. This work forms the foundation for extension of the CPA model to predict IVIS task times in a moving vehicle, to reflect the demands of the dual-task driving scenario.

Chapter 8: Visual Attention on the Move: There Is More to Modelling Than Meets the Eye. The use of CPA to predict single-task IVIS interaction times was demonstrated in Chapter 7. The aim of the study presented in Chapter 8 was to investigate how the CPA model could be extended for accurate prediction of dual-task IVIS interaction times, for instance, tasks performed at the same time as the primary driving task. Two models of visual behaviour were proposed and tested against empirical IVIS task times: one model tested the 'separate glances' hypothesis whilst the other tested the 'shared glances' hypothesis. The model that incorporated 'shared glances', in which visual attention is used to obtain information from both the IVIS and road scene simultaneously, produced the most precise predictions of IVIS task time. The findings of this study raise important questions about the division of visual attention between primary and secondary tasks. It appears that peripheral visual monitoring can be utilised in a dual-task environment, although it is likely that certain types of visual information are more suited to peripheral processing than others. Further investigation of shared glances will improve the precision of future dual-task HCI models and will be useful in the design of interfaces to enable peripheral processing.

Chapter 9: Summary of Contributions and Future Challenges. Chapter 9 summarises the work presented in this book and explores the findings using a number

of key questions that arose during the project. The implications of the research are discussed along with the future challenges in the area of IVIS design and evaluation.

The work presented in this book contributes to the understanding and evaluation of usability in the context of IVIS. The definitions and criteria for usability in an IVIS context will be useful to structure future studies of driver-vehicle interactions and in the development of new interaction strategies. The toolkit of analytic and empirical evaluation techniques was based on a comprehensive review of Ergonomics methods: this will provide a valuable reference tool, offering information not only on the output of various methods, but also on their utility at various stages throughout the product design process. The IVIS evaluation case studies have identified usability issues which limit the success of current interaction strategies and have highlighted the importance of optimisation between individual components of HMI. The CPA method was extended for quantitative predictions of IVIS interaction times in both stationary and moving vehicle situations: this was targeted at automotive manufacturers to address a need for early-stage product evaluation. The 'shared glance' hypothesis, which was developed as a result of work on the CPA model, contributes to the knowledge of visual processing in dual-task environments. Modelling the visual aspect of the driver-IVIS interaction more precisely will result in more accurate predictions of the effect of IVIS use on driving. This information will be useful in the development of more usable IVIS, with the goal of enhancing the driving experience and reducing distraction.

References

Abraham, S., 1979. Weight and height of adults 18–74 years of age. United States vital health statistics data from the National Health Survey, series 11. National Centre for Health Statistics, Rockville, MD.

Ackerman, P.L., Cianciolo, A.T., 1999. Psychomotor abilities via touch-panel testing: Measurement innovations, construct, and criterion validity. *Human Performance*. 12, 231–273.

Adler, P.S., Winograd, T.A., 1992. *Usability: Turning technologies into tools*. University Press, Oxford.

Agah, A., 2000. Human interactions with intelligent systems: Research taxonomy. *Computers and Electrical Engineering*. 27, 71–107.

Alliance of Automobile Manufacturers, 2006. Statement of principles, criteria and verification procedures on driver interactions with advanced in-vehicle information and communication systems. AAM, Washington DC.

Alonso-Ríos, D., Vázquez-García, A., Mosqueira-Rey, E., Moret-Bonillo, V., 2010. Usability: A critical analysis and a taxonomy. *International Journal of Human-Computer Interaction*. 26, 53–74.

Amditis, A., Polychronopoulos, A., Andreone, L., Bekiaris, E., 2006. Communication and interaction strategies in automotive adaptive interfaces. *Cognition, Technology and Work*. 8, 193–199.

Anderson, J.R., Lebiere, C., 1998. *The atomic components of thought*. Lawrence Erlbaum, Hillsdale, NJ.

Andre, A.D., Wickens, C.D., October 1995. When users want what's not best for them. *Ergonomics in Design*, 10–13.

Angell, L., Auflick, J., Austria, P.A., Kochhar, D., Tijerina, L., Biever, W., Diptiman, T., Hogsett, J., Kiger, S., 2006. Driver workload metrics task 2 final report. Crash Avoidance Metrics Partnership, Farmington Hills, MI.

Annett, J., 2002. Subjective rating scales: Science or art? *Ergonomics*. 45, 966–987.

Anttila, V., Luoma, J., 2005. Surrogate in-vehicle information systems and driver behaviour in an urban environment: A field study on the effects of visual and cognitive load. *Transportation Research Part F: Traffic Psychology and Behaviour*. 8, 121–133.

AT&T, 2012. 1946: First mobile telephone call [Online]. Available from: http://www.corp.att.com/attlabs/reputation/timeline/46mobile.html. [Accessed 15.05.2012].

Au, F.T.W., Baker, S., Warren, I., Dobbie, G., 2008. Automated usability testing framework. *9th Australasian User Interface Conference*, Wollongong, Australia, January 22–25, 2008, Australian Computer Society.

Averbach, E., Coriell, A.S., 1961. Short-term memory in vision. *Bell System Technical Journal*. 40, 309–328.

Azuma, S., Nishida, K., Hori, S., 1994. The future of in-vehicle navigation systems. *Vehicle Navigation and Information Systems Conference*, Yokohama, Japan, August 31–September 2, 1994, IEEE.

Baber, C., 2002. Commentary: Subjective evaluation of usability. *Ergonomics*. 45, 1021–1025.

Baber, C., 2005a. Critical path analysis for multimodal activity, in: N. Stanton, A. Hedge, K. Brookhuis, E. Salas and H. Hendrick (eds.). *Handbook of human factors and ergonomics methods*. CRC Press, London, pp. 1–8.

Baber, C., 2005b. Evaluation in human-computer interaction, in: J.R. Wilson and N. Corlett (eds.). *Evaluation of human work*. Taylor & Francis, London, pp. 357–387.

Baber, C., Butler, M., 2012. Expertise in crime scene examination: Comparing search strategies of expert and novice crime scene examiners in simulated crime scenes. *Human Factors*. 54, 413–424.

Baber, C., Mellor, B., 2001. Using critical path analysis to model multimodal human-computer interaction. *International Journal of Human-Computer Studies*. 54, 613–636.

Baber, C., Stanton, N.A., 1996. Human error identification techniques applied to public technology: Predictions compared with observed use. *Applied Ergonomics*. 27, 119–131.

Bach, K.M., Jæger, M.G., Skov, M.B., Thomassen, N.G., 2008. You can touch but you can't look: Interacting with in-vehicle systems. *CHI 2008 Conference on Human Factors in Computing Systems*, Florence, 5–10 April, 2008, ACM.

Baldwin, C.L., 2002. Designing in-vehicle technologies for older drivers: Application of sensory-cognitive interaction theory. *Theoretical Issues in Ergonomics Science*. 3, 307–329.

Bangor, A., Kortum, P.T., Miller, J.T., 2008. An empirical evaluation of the system usability scale. *International Journal of Human-Computer Interaction*. 24, 574–594.

Barón, A., Green, P., 2006. Safety and usability of speech interfaces for in-vehicle tasks while driving: A brief literature review. University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.

Baumann, M., Keinath, A., Krems, J.F., Bengler, K., 2004. Evaluation of in-vehicle HMI using occlusion techniques: Experimental results and practical implications. *Applied Ergonomics*. 35, 197–205.

Bayly, M., Young, K.L., Regan, M.A., 2009. Sources of distraction inside the vehicle and their effects on driving performance, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 191–213.

Beirness, D.J., Simpson, A.P., Pak, A., 2002. The road safety monitor: Driver distraction. Traffic Injury Research Foundation, Ontario, Canada.

Bevan, N., 1991. What is usability? *4th International Conference on Human-Computer Interaction*, Stuttgart, September 1–6, 1991, Elsevier.

Bevan, N., 1995. Usability is quality of use. *6th International Conference on Human-Computer Interaction*, Tokyo, July 9–14, 1995, Elsevier.

Bevan, N., 1999. Design for usability. *8th International Conference on Human-Computer Interaction*, Munich, August 22–26, 1999, Lawrence Erlbaum.

Bevan, N., 2001. International standards for HCI and usability. *International Journal of Human-Computer Studies*. 55, 532–552.

Bevan, N., Macleod, M., 1994. Usability measurement in context. *Behaviour and Information Technology*. 13, 1994.

Bhise, V.D., Dowd, J.D., Smid, E., 2003. A comprehensive HMI evaluation process for automotive cockpit design. *SAE World Congress*, Detroit, MI, March 3–6, 2003, SAE International.

Birrell, S.A., Young, M.S., Jenkins, D.P., Stanton, N.A., 2011. Cognitive work analysis for safe and efficient driving. *Theoretical Issues In Ergonomics Science*. 13, 430–449.

Blandford, A., Rugg, G., 2002. A case study on integrating contextual information with analyltical usability evaluation. *International Journal of Human-Computer Studies*. 57, 75–99.

Booth, P., 1989. *An introduction to human-computer interaction*. Lawrence Erlbaum, East Sussex.

Bouchner, P., Novotný, S., Piekník, R., 2007. Objective methods for assessments of influence of IVIS (in-vehicle information systems) on safe driving. *4th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Stevenson, WA, July 9–12, 2007, Elsevier.

Broadbent, D.E., 1982. Task combination and selective intake of information. *Acta Psychologica*. 50, 199–326.

Brook-Carter, N., Stevens, A., Reed, N., Thompson, S., 2009. Technical note: Practical issues in the application of occlusion to measure visual demands imposed on drivers by in-vehicle tasks. *Ergonomics*. 52, 177–186.

Brooke, J., 1996. SUS: A 'quick and dirty' usability scale, in: P.W. Jordan, B. Thomas, B.A. Weerdmeester and I.L. Mcclelland (eds.). *Usability evaluation in industry*. Taylor & Francis, London, pp. 189–94.

Broström, R., Bengtsson, P., Axelsson, J., 2011. Correlation between safety assessments in the driver-car interaction design process. *Applied Ergonomics*. 42, 575–582.

Broström, R., Engström, J., Agnvall, A., Markkula, G., 2006. Towards the next generation intelligent driver information system (IDIS): The Volvo car interaction manager concept. Volvo Car Corporation, Gothenburg.

Buckle, P., 2011. The perfect is the enemy of the good—ergonomics research and practice. IEHF Annual Lecture, 2010. *Ergonomics*. 54, 1–11.

Bullinger, H.-J., Dangelmaier, M., 2003. Virtual prototyping and testing of in-vehicle interfaces. *Ergonomics*. 46, 41–51.

Burnett, G., 2000. Usable vehicle navigation systems: Are we there yet? *Vehicle Electronic Systems European Conference and Exhibition*, Leatherhead, UK, June 29–30, 2000, ERA Technology.

Burnett, G., Porter, J.M., 2001. Ubiquitous computing within cars: Designing controls for non-visual use. *International Journal of Human Computer Studies*. 55, 521–531.

Burnett, G., Summerskill, S.J., Porter, J.M., 2004. On-the-move destination entry for vehicle navigation systems: Unsafe by any means? *Behaviour and Information Technology*. 23, 265–272.

Burns, P., Harbluk, J., Foley, J.P., Angell, L., 2010. The importance of task duration and related measures in assessing the distraction potential of in-vehicle tasks. *Second International Conference on Automotive User Interface and Interactive Vehicular Applications*—Automotive UI, Pittsburgh, PA, November 11–12, 2010, ACM.

Burns, P.C., Trbovich, P.L., Harbluk, J.L., McCurdie, T., 2005. Evaluating one screen/one control multifunction devices in vehicles. *19th International Technical Conference on the Enhanced Safety of Vehicles*, Washington, DC, June 6–9, 2005, NHTSA.

Busswell, G.T., 1922. *Fundamental reading habits: A study of their development*. University of Chicago, Chicago, IL.

Butler, K.A., January 1996. Usability engineering turns 10. *Interactions*, 58–75.

Butters, L.M., Dixon, R.T., 1998. Ergonomics in consumer product evaluation: An evolving process. *Applied Ergonomics*. 29, 55–58.

Byrne, M.D., 2001. ACT-R/PM and menu selection: Applying a cognitive architecture to HCI. *International Journal of Human Computer Studies*. 55, 41.

Cacciabue, P.C., Martinetto, M., 2006. A user-centred approach for designing driver support systems: The case of collision avoidance. *Cognition, Technology and Work*. 8, 201–214.

Caple, D.C., 2010. The IEA contribution to the transition of ergonomics from research to practice. *Applied Ergonomics*. 41, 731–737.

Car Connectivity Consortium, 2011. Car Connectivity Consortium unveils MirrorLink Roadmap [Online]. Available from: http://www.terminalmode.org/news-and-events/press-releases.html. [Accessed 15.05.2012].

Card, S.K., English, W.K., Burr, B.J., 1978. Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. *Ergonomics*. 21, 601–613.

Card, S.K., Moran, T.P., Newell, A., 1983. *The psychology of human-computer interaction*. Lawrence Erlbaum, London, UK.

Carroll, J.M., 2010. Conceptualizing a possible discipline of human-computer interaction. *Interacting with Computers*. 22, 3–12.

Carsten, O.M.J., 2004. Implications of the first set of HASTE results on driver distraction. Behavioural research in road safety 2004: Fourteenth seminar, London, Department for Transport.

Carsten, O.M.J., Merat, N., Janssen, W.H., Johansson, E., Fowkes, M., Brookhuis, K.A., 2005. HASTE final report. Institute for Transport Studies, University of Leeds, Leeds.

Cellario, M., 2001. Human-centered intelligent vehicles: Toward multimodal interface integration. *IEEE Intelligent Transport Systems*. 16, 78–81.

Chamorro-Koc, M., Popovic, V., Emmison, M., 2008. Human experience and product usability: Principles to assist the design of user-product interactions. *Applied Ergonomics*. 40, 648–656.

Chapanis, A., 1950. *Research techniques in human engineering*. John Hopkins University Press, Baltimore, MD.

Cherri, C., Nodari, E., Toffetti, A., 2004. Review of existing tools and methods: AIDE deliverable 2.1.1. Volvo Technology Corporation (VTEC), Gothenburg.

Chestnut, J., Aryal, B., Gellatly, A.W., Kleiss, J.A., 2005. A user-based qualitative usability assessment and design support assessment tool. *SAE World Congress*, Detroit, MI, April 11–14, 2005, Society of Automotive Engineers.

Chiang, D.P., Brooks, A.M., Weir, D.H., 2004. On the highway measures of driver glance behavior with an example automobile navigation system. *Applied Ergonomics*. 35, 215–223.

Cobb, J.G., 2002. Menus behaving badly. *The New York Times*, [Online]. The New York Times Company. Available from: http://www.nytimes.com/2002/05/12/automobiles/menus-behaving-badly.html. [Accessed 21.06.2012].

Cockburn, A., Gutwin, C., Greenberg, S., 2007. A predictive model of menu performance. *CHI 2007 Conference on Human Factors in Computing Systems*, San Jose, CA, April 28–May 3, 2007, ACM.

Collet, C., Guillot, A., Petit, C., 2010a. Phoning while driving I: A review of epidemiological, psychological, behavioural and physiological studies. *Ergonomics*. 53, 589–601.

Collet, C., Guillot, A., Petit, C., 2010b. Phoning while driving II: A review of driving conditions influence. *Ergonomics*. 53, 602–616.

Commission of the European Communities, 2008. Commission recommendation of 26/V/2008 on safe and efficient in-vehicle information and communication systems: Update of the European statement of principles on human-machine interface. Commission of the European Communities, Brussels.

Cox, K., Walker, D., 1993. *User-interface design*. Prentice Hall, London.

Crundall, D., Underwood, G., Chapman, P., 2002. Attending to the peripheral world while driving. *Applied Cognitive Psychology*. 16, 459–475.

Cunningham, W., 2007. Driving it: Car interfaces and usability. *CNET Reviews* [Online]. CBS Interactive. Available from: http://reviews.cnet.com/4520-10895_7-6744922-1.html. [Accessed 21.06.2012].

Daimler, 2012. Prevention: Drowsiness-detection system warns drivers to prevent them falling asleep momentarily [Online]. Daimler. Available from: http://www.daimler.com/dccom/0-5-1210218-1-1210332-1-0-0-1210228-0-0-135-0-0-0-0-0-0-0-0.html. [Accessed 06.08.2012].

Daimon, T., Kawashima, H., 1996. New viewpoints for the evaluation of in-vehicle information systems: Applying methods in cognitive engineering. *JSAE Review*. 17, 151–157.

Damiani, S., Deregibus, E., Andreone, L., 2009. Driver-vehicle interfaces and interaction: Where are they going? *European Transport Research Review*. 1, 87–96.

Darwin, C.J., Turvey, M.T., Crowder, R.G., 1972. An auditory analogue of Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive Psychology*. 3, 255–267.

Dehnig, W., Essig, H., Maass, S., 1981. *The adaptation of virtual man-computer interfaces to user requirements in dialogs*. Springer-Verlag, Berlin.

Department for Transport, 2011a. *Reported road casualties in Great Britain: Annual report 2010*. DfT, London.

Department for Transport, 2011b. *Strategic framework for road safety*. DfT, London.

Department for Transport, 2012. *Reported road casualties in Great Britain: Main results 2011*. DfT, London.

Dewar, R.E., Fenno, D., Garvey, P.M., Kuhn, B.T., Roberts, A.W., Schieber, F., Vincent, A., Yang, C.Y.D., Yim, Y.B., 2000. *User information systems: Developments and issues for the 21st century*. Transportation Research Board, Washington, DC.

de Winter, J.C.F., de Groot, S., Mulder, M., Wieringa, P.A., Dankelman, J., Mulder, J.A., 2009. Relationships between driving simulator performance and driving test results. *Ergonomics*. 52, 137–153.

Dillon, A., 2009. Inventing HCI: The grandfather of the field. *Interacting with Computers*. 21, 367–369.

Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., Perez, M.A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z.R., Jermeland, J., Knipling, R.R., 2006. *The 100-car naturalistic driving study, phase II—results of the 100-car field experiment*. National Highway Traffic Safety Administration, Washington, DC.

Dix, A., 2010. Human-computer interaction: A stable discipline, a nascent science, and the growth of the long tail. *Interacting with Computers*. 22, 13–27.

Doubleday, A., Ryan, M., Springett, M., Sutcliffe, A., 1997. A comparision of usability techniques for evaluating design. *Designing Interactive Systems Conference*, Amsterdam, August 18–20, 1997, ACM.

Douglas, S.A., Mithal, A.K., 1997. *The ergonomics of computer pointing devices*. Springer-Verlag, London.

Drews, F.A., Pasupathi, M., Strayer, D.L., 2008. Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied*. 14, 392–400.

Driver, J., Bayliss, G.C., 1989. Movements and visual attention: The spotlight metaphor breaks down. Journal of Experimental Psychology: *Human Perception and Performance*. 15, 448–456.

Duchowski, A.T., 2007. *Eye tracking methodology theory and practice*. Springer-Verlag, London.

Dukic, T., Hanson, L., Holmqvist, K., Wartenberg, C., 2005. Effect of button location on driver's visual behaviour and safety perception. *Ergonomics*. 48, 399–410.

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., Wilson, J.R., van der Doelen, B., 2012. A strategy for human factors/ergonomics: Developing the discipline and profession. *Ergonomics*. 55, 377–395.

Dul, J., Weerdmeester, B., 2001. *Ergonomics for beginners: A quick reference guide*. Taylor & Francis, London.

Dzida, W., Herda, S., Itzfeldt, W.D., 1978. User-perceived quality of interactive systems. *3rd International Conference on Software Engineering*, Atlanta, GA, May 10–12, 2001, IEEE.

Eason, K.D., 1984. Towards the experimental study of usability. *Behaviour and Information Technology*. 3, 133–143.

Empeg, 2012. Empeg: Does your car stereo run Linux? [Online]. Available from: http://www.empeg.com/. [Accessed 11.05.2012].

Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. *Human Factors*. 37, 32–64.

Engström, J., Arfwidsson, J., Amditis, A., Andreone, L., Bengler, K., Cacciabue, P.C., Eschler, J., Nathan, F., Janssen, W., 2004. Meeting the challenges of future automotive HMI design: An overview of the AIDE integrated project. *ITS Congress*, Budapest, May 24, 2004, IEEE.

The European Conference of Ministers of Transport, 2003. *Statement of principles of good practice concerning the ergonomics and safety of in-vehicle information systems*. ECMT, Leipzig.

Fang, X., Xu, S., Brzezinski, J., Chan, S.S., 2006. A study of the feasibility and effectiveness of dual-mode information presentations. *International Journal of Human-Computer Interaction*. 20, 3–17.

Farago, R., 2002. BMW iDrive. *The Truth About Cars*, [Online]. The truth about cars. Available from: http://www.thetruthaboutcars.com/2002/02/bmw-i-drive/. [Accessed 21.06.2012].

Fastrez, P., Haué, J.-B., 2008. Editorial: Designing and evaluating driver support systems with the user in mind. *International Journal of Human-Computer Studies*. 66, 125–131.

Faurote, F.L., 1907. *A busy man's textbook on automobiles*. R R Donnelley and Sons, Chicago, IL.

Fitts, P.M., 1954. The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology: General*. 47, 381–391.

Fitts, P.M., Posner, M.I., 1967. *Human performance*. Brooks Cole, CA.

Flannagan, M., Sivak, M., 1993. Indirect vision systems, in: B. Peacock and W. Karwowski (eds.). *Automotive ergonomics*. Taylor & Francis, London, pp. 205–218.

Fleetwood, M.D., Byrne, M.D., 2006. Modeling the visual search of displays: A revised ACT-R model of icon search based on eye-tracking data. *Human-Computer Interaction*. 21, 153–197.

Fleischmann, T., 2007. Model based HMI specification in an automotive context, in: M.J. Smith and G. Salvendy (eds.). *Human interface and the management of information: Methods, techniques and tools in information design*. Springer-Verlag, Berlin, pp. 31–39.

Flemming, S.A.C., Hilliard, A., Jamieson, G.A., 2008. The need for human factors in the sustainability domain. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 52, 748–752.

Franks, I.M., Goodman, D., Miller, G., 1983. Human factors in sports systems: An empirical investigation of events in team games. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 27, 383–386.

Fuller, R., 2005. Towards a general theory of driver behaviour. *Accident Analysis and Prevention*. 37, 461–472.

Gelau, C., Schindhelm, R., 2010. Enhancing the occlusion technique as an assessment tool for driver visual distraction. *IET Intelligent Transport Systems*. 4, 346–355.

Goldstein, E.B., 2002. *Sensation and perception*. Wadsworth, Pacific Grove, CA.

Gould, J.D., Lewis, C., 1985. Designing for usability: Key principles and what designers think, in: P.J. Denning (ed.). *Communications of the ACM*. ACM, New York, pp. 300–311.

Graham-Rowe, D., 2010. *Touch screens that touch back*. Massachusetts Institute of Technology, Cambridge, MA.

Gray, W.D., 2002. Simulated task environments: The role of high-fidelity simulations, scaled worlds, synthetic environments, and laboratory tasks in basis and applied cognitive research. *Cognitive Science Quarterly*. 2, 205–227.

Gray, W.D., John, B.E., Atwood, M.E., 1993. Project Ernestine: Validating a GOMS analysis for predicting and explaining real-world task performance. *Human-Computer Interaction*. 8, 237–309.

Gray, W.D., Salzman, M.C., 1998. Damaged merchandise? A review of experiments that compare usability evaluation methods. *Human-Computer Interaction*. 13, 203–261.

Green, P., 1999. The 15-second rule for driver information systems. *ITS America Ninth Annual Meeting*, Washington, DC, April 9th, 1999, Intelligent Transportation Society of America.

Green, P., 2005. How driving simulator quality can be improved. *3rd Driving Simulation Conference North America*, Orlando, FL, November 2005, Elsevier.
Green, P., Hoekstra, E., Williams, M., 1993. *Further on-the-road tests of driver interfaces: Examination of a route guidance system and a car phone*. University of Michigan Transportation Research Institue (UMTRI), Ann Arbor, MI.
Green, P., Levison, W., Paelke, G., Serafin, C., 1994. *Suggested human factors design guidelines for driver information systems*. The University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.
Green, P., Levison, W., Paelke, G., Serafin, C., 1995. *Preliminary human factors design guidelines for driver information systems*. National Technical Information Service, Springfield, Virginia, VA.
Green, P., Tsimhoni, O., 2001. Visual occlusion to assess the demands of driving and tasks: *The literature. Workshop on Exploring the Occlusion Technique: Progress in Recent Research and Applications*, Fiat Research Centre, Torino, Italy, November 12–13, 2001, UMTRI.
Greenberg, S., Buxton, B., 2008. Usability evaluation considered harmful (some of the time). *CHI 2008 Conference on Human Factors in Computing Systems*, Florence, April 5–10, 2008, ACM.
Griffin, T.G.C., Young, M.S., Stanton, N.A., 2010. Investigating accident causation through information network modelling. *Ergonomics*. 53, 198–210.
Grudin, J., 2009. Brian Shackel's contribution to the written history of Human-Computer Interaction. *Interacting with Computer*s. 21, 370–374.
Gu Ji, Y., Jin, B.S., 2010. Development of the conceptual prototype for haptic interface on the telematics system. *International Journal of Human-Computer Interaction*. 16, 22–52.
Hancock, P.A., Drury, C.G., 2011. Does human factors/ergonomics contribute to the quality of life? *Theoretical Issues in Ergonomics Science*. 12, 416–426.
Hancock, P.A., Hancock, G.M., Warm, J.S., 2009a. Individuation: The N = 1 revolution. *Theoretical Issues in Ergonomics Science*. 10, 481–488.
Hancock, P.A., Mouloua, M., Senders, J.W., 2009b. On the philosophical foundations of the distracted driver and driving distraction, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 11–30.
Hancock, P.A., Szalma, J.L., 2004. On the relevance of qualitative methods for ergonomics. *Theoretical Issues in Ergonomics Science*. 5, 499–506.
Harbluk, J.L., Noy, Y.I., Trbovich, P.L., Eizenman, M., 2007. An on-road assessment of cognitive distraction: Impacts on drivers' visual behavior and braking performance. *Accident Analysis and Prevention*. 39, 372–379.
Harrison, A., 1997. A survival guide to critical path analysis. Butterworth-Heinemann, Oxford, UK.
Hartson, H.R., 1998. HCI: Interdisciplinary roots and trends. *The Journal of Systems and Software*. 43, 103–118.
Harvey, C., Stanton, N.A., In press. The trade-off between context and objectivity in an analytic approach to the evaluation of in-vehicle interfaces. *IET Intelligent Transport Systems*. 6(3): 243–258.
Harvey, C., Stanton, N.A., Pickering, C.A., McDonald, M., Zheng, P., 2011a. Context of use as a factor in determining the usability of in-vehicle devices. *Theoretical Issues in Ergonomics Science*. 12, 318–338.
Harvey, C., Stanton, N.A., Pickering, C.A., McDonald, M., Zheng, P., 2011b. In-vehicle information systems to meet the needs of drivers. *International Journal* of *Human-Computer Interaction*. 27, 505–522.

Harvey, C., Stanton, N.A., Pickering, C.A., McDonald, M., Zheng, P., 2011c. To twist or poke? A method for identifying usability issues with the rotary controller and touch screen for control of in-vehicle information systems. *Ergonomics*. 54, 609–625.

Harvey, C., Stanton, N.A., Pickering, C.A., McDonald, M., Zheng, P., 2011d. A usability evaluation toolkit for in-vehicle information systems (IVISs). *Applied Ergonomics*. 42, 563–574.

Haslegrave, C.M., 1993. Visual aspects in vehicle design, in: B. Peacock and W. Karwowski (eds.). *Automotive ergonomics*. Taylor & Francis, London, pp. 79–98.

Hawthorn, D., 2000. Possible implications of aging for interface designers. *Interacting with Computers*. 12, 507–528.

Heaton, N.O., 1992. Defining usability. *Displays*. 13, 147–150.

Hedlund, J., Simpson, H., Mayhew, D., 2006. *International conference on distracted driving: Summary of proceedings and recommendations*. The Traffic Injury Research Foundation and The Canadian Automobile Association, Toronto.

Heide, A., Henning, K., 2006. The 'cognitive car': A roadmap for research issues in the automotive sector. *Annual Reviews in Control*. 30, 197–203.

Herriotts, P., 2005. Identification of vehicle design requirements for older drivers. *Applied Ergonomics*. 36, 255–262.

Herslund, M.-B., Jørgensen, N.O., 2003. Looked-but-failed-to-see-errors in traffic. *Accident Analysis and Prevention*. 35, 885–891.

Herzberg, F., 1996. *Work and the nature of man*. Staples Press, London.

Hewett, T.A., 1986. The role of iterative evaluation in designing systems for usability, in: M.D. Harrison and A.F. Monk (eds.). People and Computers: Designing for Usability. *Proceedings of the Second Conference of the British Computer Society Human Computer Special Interest Group*, University of York, September 23–26, 1986.

Hick, W.E., 1952. On the rate of gain of information. *Quarterly Journal of Experimental Psychology*. 4, 11–26.

Hix, D., Hartson, H.R., 1993. *Developing user interfaces: Ensuring usability through product and process*. John Wiley & Sons, Chichester.

Ho, C., Spence, C., 2008. *The multisensory driver: Implications for ergonomic car interface design*. Ashgate, Aldershot.

Hodgkinson, G.P., Crawshaw, C.M., 1985. Hierarchical task analysis for ergonomics research. *Applied Ergonomics*. 16, 289–299.

Hoedemaeker, M., Neerincx, M., 2007. Attuning in-car user interfaces to the momentary cognitive load, in: D.D. Schmorrow and L.M. Reeves (eds.). *Foundations of augmented cognition*. Springer-Verlag, Berlin, pp. 286–293.

Hoffman, J.E., 1998. Visual attention and eye movements, in: H. Pashler (ed.). *Attention*. Psychology Press, Hove, pp. 119–153.

Honda Motor Company, 2012. Honda history: A dynamic past, an exciting future [Online]. Honda. Available from: http://world.honda.com/history/. [Accessed 11.05.2012].

Horberry, T., Anderson, J., Regan, M.A., Triggs, T.J., Brown, J., 2006. Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis and Prevention*. 38, 185–191.

Hornbæk, K., 2006. Current practice in measuring usability. *International Journal of Human-Computer Studies*. 64, 79–102.

Horrey, W.J., 2011. Assessing the effects of in-vehicle tasks on driving performance. *Ergonomics in Design: The Quarterly of Human Factors Applications.* 19, 4–7.

Horrey, W.J., Alexander, A.L., Wickens, C.D., 2003. *Does workload modulate the effects of in-vehicle display location on concurrent driving and side task performance?* Aviation Human Factors Division, Institute of Aviation, University of Illinois, Savoy, IL.

Horrey, W.J., Wickens, C.D., 2007. In-vehicle glance duration: Distributions, tails and a model of crash risk. *Transportation Research Board*. 2018, 22–28.

Horrey, W.J., Wickens, C.D., Consalus, K.P., 2006. Modeling drivers' visual attention allocation while interacting with in-vehicle technologies. *Journal of Experimental Psychology: Applied*. 12, 67–78.

Howarth, P.A., 1991. Assessment of the visual environment, in: J.R. Wilson and E.N. Corlett (eds.). *Evaluation of human work: A practical ergonomics methodology*. Taylor & Francis, London, pp. 351–386.

Hulse, M.C., Dingus, T.A., Mollenhauer, M.A., Liu, Y., Jahns, S.K., Brown, T., McKinney, B., 1998. *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identification of the strengths and weaknesses of alternative information display formats*. Federal Highway Administration, Washington, DC.

Hutchins, S.G., 2011. Evaluating a macrocognition model of team collaboration using real-world data from the Haiti relief effort. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 55, 252–256.

International Organization for Standardization, 1996. DD 235. Guide to in-vehicle information systems.

International Organization for Standardization, 1998. ISO 9241. Ergonomic requirements for office work with visual display terminals (VDTs)—part 11: Guidance on usability.

International Organization for Standardization, 1999. ISO 13407. Human-centred design processes for interactive systems.

International Organization for Standardization, 2001. ISO/IEC 9126. Information technology—software product quality—part 1: Quality model.

International Organization for Standardization, 2002. ISO 15007. Road vehicles—measurement of driver visual behaviour with respect to transport information and control systems—part 1: Definitions and parameters.

International Organization for Standardization, 2003. ISO 17287. Road vehicles—ergonomic aspects of transport information and control systems—procedure for assessing suitability of use while driving.

International Organization for Standardization, 2006. ISO 202082-1. Ease of operation of everyday products—part 1: Design requirements for context of use and user characteristics.

International Organization for Standardization, 2007. BS ISO 16673:2007. Road vehicles—ergonomic aspects of transport information and control systems—occlusion method to assess visual demand due to the use of in-vehicle systems.

Jaguar Cars Limited, 2011. Jaguar: Dual-view touch-screen [Online]. Available from: http://www.jaguarxjmedia.com/ENG_ENG_dualscreen.html#/dual-screen. [Accessed 03.08.2012].

Jamson, H., Merat, N., Carsten, O., Lai, F., 2011. Fully-automated driving: The road to future vehicle. *The 6th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Lake Tahoe, CA, June 27–30, 2011, TRB.

Jamson, H.A., Merat, N., 2005. Surrogate in-vehicle information systems and driver behaviour: Effects of visual and cognitive load in simulated rural driving. *Transportation Research Part F: Traffic Psychology and Behaviour*. 8, 79–96.

Japan Automobile Manufacturers Association, 2004. Guideline for in-vehicle display systems, version 3.0. JAMA, Tokyo.

Jastrzembski, T.S., Charness, N., 2007. The model human processor and the older adult: Parameter estimation and validation within a mobile phone task. *Journal of Experimental Psychology: Applied*. 13, 224–248.

Jeffries, R., Miller, J.R., Wharton, C., Uyeda, K.M., 1991. User interface evaluation in the real world: A comparison of four techniques. *CHI 1991 Conference on Human Factors in Computing Systems*, Pittsburgh, PA, May 15–20, 1999, ACM.

Johansson, E., Engström, J., Cherri, C., Nodari, E., Toffetti, A., Schindhelm, R., Gelau, C., 2004. Review of existing techniques and metrics for IVIS and ADAS assessment. Volvo Technology Corporation (VTEC), Gothenburg.

John, B.E., 1990. Extensions of GOMS analyses to expert performance requiring perception of dynamic visual and auditory information. *Conference on Human Factors in Computing Systems—CHI 1990*, Seattle, Washington, April 1–5, 1990, ACM.

John, B.E., 2011. Using predictive human performance models to inspire and support UI design recommendations. *CHI 2011 Conference on Human Factors in Computing Systems*, Vancouver, May 7–12, 2011, ACM.

John, B.E., Gray, W.D., 1995. CPM-GOMS: An analysis method for tasks with parallel activities. *Conference on Human Factors in Computing Systems—CHI 1995*, New York, May 7–11, 1995, ACM.

John, B.E., Jastrzembski, T.S., 2010. Exploration of costs and benefits of predictive human performance modeling for design. *International Conference on Cognitive Modeling*, Philadelphia, PA, August 6–8, 2004, Psychology Press.

John, B.E., Kieras, D.E., 1996. The GOMS family of user interface analysis techniques: Comparison and contrast. *ACM Transactions on Computer-Human Interaction*. 3, 320–351.

John, B.E., Newell, A., 1987. Predicting the time to recall computer command abbreviations. *Conference on Human Factors in Computing Systems and Graphics Interface—CHI/GI 1987*, Toronto, Canada, April 5–9, 1987, ACM.

John, B.E., Prevas, K., Salvucci, D.D., Koedinger, K., 2004a. Predictive human performance modeling made easy. *Conference on Human Factors in Computing Systems—CHI 2004*, Vienna, Austria, April 24–29, 2004, ACM.

John, B.E., Salvucci, D.D., Centgraf, P., Prevas, K., 2004b. Integrating models and tools in the context of driving and in-vehicle devices. *Sixth International Conference on Cognitive Modelling*, Pittsburgh, PA, July 30–August 1, 2004, Psychology Press.

Johnson, G.I., Clegg, C.W., Ravden, S.J., 1989. Towards a practical method of user interface evaluation. *Applied Ergonomics*. 20, 255–260.

Jokela, T., Iivari, N., Matero, J., Karukka, M., 2003. The standard of user-centered design and the standard definition of usability: Analyzing ISO 13407 against ISO 9241-11, in: C.S. De Souza, A. Sànchez, S. Barbosa and C. Gonzalez (eds.). *Proceedings of the 1st Latin American Conference on Human-Computer Interaction*, Rio de Janeiro, August 17–20, 2003.

Jordan, P.W., 1998a. Human factors for pleasure in product use. *Applied Ergonomics*. 29, 25–33.

Jordan, P.W., 1998b. *An introduction to usability*. Taylor & Francis, London.

Kadar, E.E., Effken, J.A., 2005. From discrete actors to goal directed actions: Toward a process-based methodology for psychology. *Philosophical Psychology*. 18, 353–382.

Kantowitz, B., 2000. In-vehicle information systems: Premises, promises, and pitfalls. *Transportation Human Factors*. 2, 359–379.

Kantowitz, B.H., 1992. Selecting measures for human factors research. *Human Factors*. 34, 387–398.

Karwowski, W., 2006. *International encyclopedia of ergonomics and human factors*. CRC Press, Boca Raton, FL.

Kass, S.J., Cole, K.S., Stanny, C.J., 2007. Effects of distraction and experience on situation awareness and simulated driving. *Transportation Research Part F: Traffic Psychology and Behaviour*. 10, 321–329.

Kern, D., Schmidt, A., 2009. Design space for driver-based automotive user interfaces. *First International Conference on Automotive User Interfaces and Interactive Vehicular Applications—Automotive UI*, Essen, Germany, September 21–22, 2009, ACM.

Khalid, H.M., Helander, M.G., 2004. A framework for affective customer needs in product design. *Theoretical Issues in Ergonomics Science*. 5, 27–42.

Khan, A.M., Bacchus, A., Erwin, S., 2012. Policy challenges of increasing automation in driving. *IATSS Research*. 35, 79–89.

Kieras, D., 2001. *Using the keystroke-level model to estimate execution times*. University of Michigan, Ann Arbor, MI.

Kieras, D.E., Meyer, D.E., 1997. An overview of the EPIC architecture for cognition and performance with application to human-computer interaction. *Human-Computer Interaction*. 12, 391–438.

Kirwan, B., 1992a. Human error identification in human reliability assessment. Part 1: Overview of approaches. *Applied Ergonomics*. 23, 299–318.

Kirwan, B., 1992b. Human error identification in human reliability assessment. Part 2: Detailed comparison of techniques *Applied Ergonomics*. 23, 371–381.

Kirwan, B., Ainsworth, L.K., 1992. *A guide to task analysis*. Taylor & Francis, London.

Klauer, S.G., Dingus, T.A., Neale, V.L., Sudweeks, J., Ramsey, D.J., 2006. *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data*. Virginia Tech Transportation Institute, Blacksburg, VA.

Koninklijke Philips Electronics, 2012. Key Inventions [Online]. Available from: http://www.philips.com/about/company/history/keyinventions/index.page. [Accessed 15.05.2012].

Kontogiannis, T., Embrey, D., 1997. A user-centred design approach for introducing computer-based process information systems. *Applied Ergonomics*. 28, 109–119.

Kramer, A.F., McCarley, J.S., 2003. Oculomotor behaviour as a reflection of attention and memory processes: Neural mechanisms and applications to human factors. *Theoretical Issues in Ergonomics. Science*. 4, 21–55.

Kujala, T., Saariluoma, P., 2001. Effects of menu structure and touch screen scrolling style on the variability of glance durations during in-vehicle visual search tasks. *Ergonomics*. 54, 716–732.

Kurosu, M., 2007. Concept of usability revisited. *CH1 2007 Conference on Human-Computer Interaction*, Berlin, July 22–27, 2007.

Kwahk, J., Han, S.H., 2002. A methodology for evaluating the usability of audiovisual consumer electronic products. *Applied Ergonomics*. 33, 419–431.

Landau, K., 2002. Usability criteria for intelligent driver assistance systems. *Theoretical Issues in Ergonomics Science*. 3, 330–345.

Landauer, T.K., 1997. Behavioral research methods in human-computer interaction, in: M. Helander, T.K. Landauer and P. Prabhu (eds.). *Handbook of human-computer interaction*. Elsevier Science, Oxford, pp. 203–227.

Langham, M., Hole, G., Edwards, J., O'Neil, C., 2002. An analysis of 'looked but failed to see' accidents involving parked police vehicles. *Ergonomics*. 45, 167–185.

Lansdale, M.W., Ormerod, T.C., 1994. *Understanding interfaces: A handbook of human-computer dialogue*. Academic Press, London.

Lansdown, T.C., 2000. Driver visual allocation and the introduction of intelligent transport systems. *Proceedings of the Institution of Mechanical Engineers, part D: Journal of Automobile Engineering*. 214, 645–652.

Lansdown, T.C., Brook-Carter, N., Kersloot, T., 2002. Primary task disruption from multiple in-vehicle systems. *Intelligent Transportation Systems Journal*. 7, 151–168.

Lansdown, T.C., Brook-Carter, N., Kersloot, T., 2004a. Distraction from multiple in-vehicle secondary tasks: Vehicle performance and mental workload implications. *Ergonomics*. 47, 91–104.

Lansdown, T.C., Burns, P.C., Parkes, A.M., 2004b. Perspectives on occlusion and requirements for validation. *Applied Ergonomics*. 35, 225–232.

Lee, J., 1986. Letter to the editor: Conceptual subtleties of the percentile. *International Journal of Epidemiology*. 15, 141–142.

Lee, J.D., Young, K.L., Regan, M.A., 2009. Defining driver distraction, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 31–40.

Lees, M.N., Lee, J.D., 2007. The influence of distraction and driving context on driver response to imperfect collision warning systems. *Ergonomics*. 50, 1264–1286.

Lévesque, V., Oram, L., MacLean, K., Cockburn, A., Marchuk, N.D., Johnson, D., Colgate, J.E., Peshkin, M.A., 2011. Frictional widgets: Enhancing touch interfaces with programmable friction. *CH1 2011 Conference on Human Factors in Computing Systems*, Vancouver, May 7–12, 2011, ACM.

Lexus, 2012. Advanced pre-collision system (ACPS) with driver attention monitor [Online]. Lexus. Available from: http://www.lexus.com/models/LSh/features/safety/advanced_precollision_system_apcs_with_driver_attention_monitor.html#disclaimer_1. [Accessed 06.08.2012].

Lindgaard, G., 2009. Early traces of usability as a science and as a profession. *Interacting with Computers*. 21, 350–352.

Lindgaard, G., Whitfield, T.W.A., 2004. Integrating aesthetics within an evolutionary and psychological framework. *Theoretical Issues in Ergonomics Science*. 5, 73–90.

Liu, C.-C., Doong, J.-L., Hsu, C.-C., Huang, W.-S., Jeng, M.-C., 2009. Evidence for the selective attention mechanism and dual-task interference. *Applied Ergonomics*. 40, 341–347.

Liu, Y.-C., 2000. Effect of advanced traveler information displays on younger and older drivers' performance. *Displays*. 21, 161–168.

Liu, Y.-C., Bligh, T., Chakrabarti, A., 2003. Towards an 'ideal' approach for concept generation. *Design Studies*. 24, 341–355.

Llaneras, R.E., Singer, J.P., 2002. *Inventory of in-vehicle technology human factors design characteristics*. National Highway Traffic Safety Administration, Washington, DC.

Lockhart, T.E., Shi, W., 2010. Effects of age on dynamic accommodation. *Ergonomics*. 53, 892–903.

Lockyer, K., 1984. *Critical path analysis and other project network techniques*. Pitman, London, UK.

Long, J., 2010. Some celebratory HCI reflections on a celebratory HCI festschrift. *Interacting with Computers*. 22, 68–71.

Long, J.B., 1986. People and computers: Designing for usability, in: M.D. Harrison and A.F. Monk (eds.). *2nd Conference of the British Computer Society Human Computer Interaction Specialist Group*, University of York, September 23–26, 1986.

Ludvigsen, K.E., 1997. A century of automobile comfort and convenience, in: Society of Automotive Engineers Historical Committee. Committee (ed.). *The automobile: A century of progress. Society of Automotive Engineers (SAE)*, Pennsylvania, pp. 99–120.

Lyons, M., 2009. Towards a framework to select techniques for error prediction: Supporting novice users in the healthcare sector. *Applied Ergonomics*. 40, 379–395.

Ma, R., Kaber, D.B., 2007. Situation awareness and driving performance in a simulated navigation task. *Ergonomics*. 50, 1351–1364.

Macdonald, A.S., 1998. Developing a quantitative sense, in: N. Stanton (ed.). *Human factors in consumer products*. Taylor & Francis, London, pp. 175–191.

Mackay, W.E., 2004. The interactive thread: Exploring methods for multi-disciplinary design. *5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, Cambridge, MA, August 1–4, 2004, ACM.

Maguire, M., Kirakowski, J., Vereker, N., 1998. *RESPECT: User centred requirements handbook*. Ergonomics and Safety Research Institute (ESRI), Loughborough.

Manes, D., Green, P., Hunter, D., 1997. *Prediction of destination entry and retrieval times using keystroke-level models*. The University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.

Marcus, A., January–February 2004. Vehicle user interfaces: The next revolution. *Interactions*, 40–47.

Matthews, M.L., Bryant, D.J., Webb, R.D.G., Harbluk, J.L., 2001. Model for situation awareness and driving: Application to analysis and research for intelligent transportation systems. *Transportation Research Record*. 1779, 26–32.

McClelland, I., 1991. Product assessment and user trials, in: J.R. Wilson and E.N. Corlett (eds.). *Evaluation of human work: A practical ergonomics methodology*. Taylor & Francis, London, pp. 218–247.

McMains, S.A., Somers, D.C., 2004. Multiple spotlights of attentional selection in human visual cortex. *Neuron*. 42, 677–686.

Meister, D., 1989. *Conceptual aspects of human factors*. John Hopkins University Press, Baltimore, MD.

Meister, D., 1992. Some comments on the future of ergonomics. *International Journal of Industrial Ergonomics*. 10, 257–260.

Mendoza, P.A., Angelelli, A., Lindgren, A., 2011. Ecological interface design inspired human machine interface for advanced driver assistance systems. *IET Intelligent Transport Systems*. 5, 53–39.

Monk, C.A., Kidd, D.G., 2007. R we fooling ourselves: Does the occlusion technique shortchange R estimates? *Fourth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Stevenson, WA, July 9–12, 2007, TRB.

Moran, J., 2009. Paradise lost [Online]. BBC Magazine. Available from: http://news.bbc.co.uk/1/hi/magazine/8133890.stm. [Accessed Tuesday 7th July, 2009].

Motorola Solutions, 2012. A legacy of innovation: Timeline of Motorola history since 1928 [Online]. Available from: http://www.motorola.com/staticfiles/Business/Corporate/US-EN/history/feature-car-radio.html. [Accessed 11.05.2012].

Mourant, R.R., Herman, M., Moussa-Hamouda, E., 1980. Direct looks and control location in automobiles. *Human Factors*. 22, 417–425.

Mourant, R.R., Rockwell, T.H., 1970. Mapping eye-movement patterns to the visual scene in driving: An exploratory study. *Human Factors*. 12, 81–87.

Muller, M.M., Malinowski, P., Gruber, T., Hillyard, S.A., 2003. Sustained division of the attentional spotlight. *Nature*. 424, 309–312.

Munipov, V.M., 1992. Chernobyl operators: Criminals or victims? *Applied Ergonomics*. 23, 337–342.

Murdock, B.B., 1961. Short-term retention of single paired-associates. *Journal of Experimental Psychology*. 65, 433–443.

National Highway Traffic Safety Administration, 2012. What is distracted driving? [Online]. NHTSA. Available from: http://www.distraction.gov/content/get-the-facts/facts-and-statistics.html. [Accessed 02.08.2012].

Newcomb, T.P., Spurr, R.T., 1989. *A technical history of the motor car*. Adam Hilger, Bristol.

Nielsen, J., 1992. Finding usability problems through heuristic evaluation. *CHI 1992 Conference on Human Factors in Computing Systems*, Monterey, CA, May 3–7, 1992, ACM.

Nielsen, J., 1993. *Usability engineering*. Academic Press, London.

Nielsen, J., 2005. Ten usability heuristics [Online]. Available from: http://www.useit.com/papers/heuristic/heuristic_list.html. [Accessed 20.03.09].

Nielsen, J., Nov–Dec 2006. Logic versus usage: The case for activity-centered design. *Interactions*, 45.

Nielsen, J., 2009. Usability 101: Introduction to usability [Online]. Available from: http://www.useit.com/alertbox/20030825.html. [Accessed 22 May, 2009].

Nielsen, J., Phillips, V.L., 1993. Estimating the relative usability of two interfaces: Heuristic, formal, and empirical methods compared. *CHI 1993 Conference on Human Factors in Computing Systems*, Amsterdam, April 24–29, 1993, ACM.

Noel, E., Nonnecke, B., Trick, L., 2005. A comprehensive learnability evaluation method for in-car navigation devices. Society of Automotive Engineers, Washington, DC.

Nokia, 2009. History of Nokia part one: Nokia firsts [Online]. Available from: http://conversations.nokia.com/2009/01/19/history-of-nokia-part-one-nokia-firsts/. [Accessed 15.05.2012].

Norman, D.A., 1983. Design principles for human computer interfaces. *SIGCHI Conference on Human Factors in Computing Systems*, Boston, MA, December 12–15, 1983, ACM.

Norman, D.A., 2002. *The design of everyday things*. Basic Books, New York.

Norman, D.A., Draper, S.W., 1986. *User centered system design: New perspectives on human-computer interaction*. Lawrence Erlbaum, London.

Nowakowski, C., Green, P., 2001. Prediction of menu selection times parked and while driving using the SAE J2365 method. University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.

Nowakowski, C., Utsui, Y., Green, P., 2000. *Navigation system destination entry: The effects of driver workload and input devices, and implications for SAE recommended practice*. University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.

Noy, Y.I., Lemoine, T.L., Klachan, C., Burns, P.C., 2004. Task interruptability and duration as a measure of visual distraction. *Applied Ergonomics*. 35, 207–213.

Noyes, J., 2009. Telescreens, keypens, and the expert: A 60 year snapshot. *Interacting with Computers*. 21, 335–338.

Oliver, K.J., Burnett, G.E., 2008. Learning-oriented vehicle navigation systems: A preliminary investigation in a driving simulator. *Mobile HCI*, Amsterdam, September 2–5, 2008, ACM.

Olson, J.R., Olson, G.M., 1990. The growth of cognitive modeling in human-computer interaction since GOMS. *Human-Computer Interaction*. 5, 221–265.

Olson, J.S., Moran, T.P., 1996. Mapping the method muddle: Guidance in using methods for user interface design, in: M. Rudisill, C. Lewis, P.G. Polson and T.D. Mackay (eds.). *Human-computer interface designs: Success stories, emerging methods, and real world context*. Kaufmann, San Francisco, pp. 269–300.

Olson, P.L., 1993. Vision and perception, in: B. Peacock and W. Karwowski (eds.). *Automotive ergonomics*. Taylor & Francis, London, pp. 161–184.

Pashler, H.E., 1998. *The psychology of attention*. MIT Press, Cambridge, MA.

Pauzié, A., 2008. Evaluating driver mental workload using the driving activity load index (DALI). *1st European Conference on Human Centred Design for Intelligent Transport Systems*, Lyon, 3–4 April, 2008, INRETS.

Peacock, B., Karwowski, W., 1993. *Automotive ergonomics*. Taylor & Francis, London.

Peterson, L.R., Peterson, M.J., 1959. Short-term retention of individual verbal items. *Journal of Experimental Psychology*. 58, 193–198.

Pettitt, M., Burnett, G., Stevens, A., 2005. Defining driver distraction. *World Congress on Intelligent Transport Systems*, San Francisco, CA, November 6–10, 2005, Curran Associates.

Pettitt, M., Burnett, G., Stevens, A., 2007. An extended keystroke level model (KLM) for predicting the visual demand of in-vehicle information systems. *CHI 2007 Conference on Human Factors in Computing Systems*, San Jose, CA, April 28–May 3, 2007, ACM.

Pheasant, S., 1996. *Bodyspace: Anthropometry, ergonomics, and the design of work*. CRC Press, London, UK.

Pickering, C.A., Burnham, K.J., Richardson, M.J., 2007. A review of automotive human machine interface technologies and techniques to reduce driver distraction. *2nd IET International Conference on System Safety*, London, UK, October 22–24, 2007, IET.

Piechulla, W., Mayser, C., Gehrke, H., König, W., 2003. Reducing drivers' mental workload by means of an adaptive man-machine interface. *Transportation Research Part F: Traffic Psychology and Behaviour*. 6, 233–248.

Pioneer Europe, 2012. History [Online]. Available from: http://www.pioneer.eu/uk/content/company/company/history.html. [Accessed 14.05.2012].

Plant, K.L., Stanton, N.A., 2012. Why did the pilots shut down the wrong engine? Explaining errors in context using schema theory and the perceptual cycle model. *Safety Science*. 50, 300–315.

Posner, M.I., Petersen, S.E., 1990. The attention system of the human brain. *Annual Review of Neuroscience*. 13, 25–42.

Preece, J., Rogers, Y., Sharp, H., 2002. *Interaction design: Beyond human-computer interaction*. John Wiley & Sons, New Jersey.

Rakotonirainy, A., Tay, R., 2004. In-vehicle ambient intelligent transport systems (I-VAITS): Towards an integrated research. *7th International IEEE Conference on Intelligent Transportation Systems*, Washington, DC, October 3–6, 2004, IEEE.

Rantanen, E.M., Goldberg, J.H., 1999. The effect of mental workload on the visual field size and shape. *Ergonomics*. 42, 816–834.

Ravden, S., Johnson, G., 1989. *Evaluating usability of human-computer interfaces: A practical method*. Ellis Horwood, Chichester.

Reed, M.P., Green, P.A., 1999. Comparison of driving performance on-road and in a low-cost simulator using a concurrent telephone dialling task. *Ergonomics*. 42, 1015–1037.

Reed-Jones, J., Trick, L.M., Matthews, M., 2008. Testing assumptions implicit in the use of the 15-second rule as an early predictor of whether an in-vehicle device produces unacceptable levels of distraction. *Accident Analysis and Prevention*. 40, 628–634.

Regan, M.A., Lee, J.D., Young, K.L., 2009. Introduction, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, FL, pp. 3–7.

Reimer, B., Mehler, B., Coughlin, J.F., Roy, N., Dusek, J.A., 2011. The impact of a naturalistic hands-free cellular phone task on heart rate and simulated driving performance in two age groups. *Transportation Research part F: Traffic Psychology and Behaviour*. 14, 13–25.

Rennie, A.M., 1981. The application of ergonomics to consumer product evaluation. *Applied Ergonomics*. 12, 163–168.

Richardson, J.F., Pincherle, G., 1969. Heights and weights of British businessmen. *British Journal of Preventative and Social Medicine*. 23, 267–270.

Richter, H., Ecker, R., Deisler, C., Butz, A., 2010. HapTouch and the 2+1 state model: Potentials of haptic feedback on touch based in-vehicle information systems. *Automotive UI 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, Pittsburgh, PA, November 11–12, 2010, University of Pittsburgh.

Rogé, J., Pébayle, T., Kiehn, L., Muzet, A., 2002. Alteration of the useful visual field as a function of state of vigilance in simulated car driving. *Transportation Research Part F: Traffic Psychology and Behaviour*. 5, 189–200.

Rogé, J., Pébayle, T., Lambilliotte, E., Spitzenstetter, F., 2004. Influence of age, speed and duration of monotonous driving task in traffic on the driver's useful field of view. *Vision Research*. 44, 2737–2744.

Rogers, W.A., Fisk, A.D., McLaughlin, A.C., Pak, R., 2005. Touch a screen or turn a knob: Choosing the best device for the job. *Human Factors*. 47, 271–288.

Rosenbaum, S., Skinner, R.K., 1985. A survey of heights and weights of adults in Great Britain, 1980. *Annals of Human Biology*. 12, 115–127.

Rudin-Brown, C.M., 2010. 'Intelligent' in-vehicle intelligent transport systems: Limiting behavioural adaptation through adaptive design. *IET Intelligent Transport Systems*. 4, 252–261.

Rumar, K., 1993. Road user needs, in: A.M. Parkes and S. Franzén (eds.). *Driving future vehicles*. Taylor & Francis, London, pp. 41–48.

Ryan, G.A., Legge, M., Rosman, D., 1998. Age-related changes in drivers' crash risk and crash type. *Accident Analysis and Prevention*. 30, 379–387.

Rydström, A., Bengtsson, P., Grane, C., Broström, R., Agardh, J., Nilsson, J., 2005. Multifunctional systems in vehicles: A usability evaluation. *CybErg 2005 International Cyberspace Conference on Ergonomics*, Johannesburg, September 15–October 15, 2005, International Ergonomics Association Press.

Salvucci, D.D., 1999. Mapping eye movements to cognitive processes. Doctoral thesis, Carnegie Mellon University, Pittsburgh, PA.

Salvucci, D.D., 2000. A model of eye movements and visual attention, in: N. Taatgen and J. Aasman (eds.). *Third International Conference on Cognitive Modeling*, Veenendaal, The Netherlands, March 23–25, 2000.

Salvucci, D.D., 2001. Predicting the effects of in-car interface use on driver performance: An integrated model approach. *International Journal of Human-Computer Studies*. 55, 85–107.

Salvucci, D.D., Zuber, M., Beregovaia, E., Markley, D., 2005. Distract-R: Rapid prototyping and evaluation of in-vehicle interfaces. *CHI 2005 Conference on Human Factors in Computing Systems*, Portland, OR, April 2–7, 2005.

Santos, J., Merat, N., Mouta, S., Brookhuis, K., deWaard, D., 2005. The interaction between driving and in-vehicle systems: Comparison of results from laboratory, simulator and real-world studies. *Transportation Research part F: Traffic Psychology and Behaviour*. 8, 135–146.

Sarter, N.B., 2006. Multimodal information presentation: Design guidance and research challenges. *International Journal of Industrial Ergonomics*. 36, 439–445.

Sauer, J., Seibel, K., Rüttinger, B., 2010. The influence of user expertise and prototype fidelity in usability tests. *Applied Ergonomics*. 41, 130–140.

Sauer, J., Sonderegger, A., 2009. The influence of prototype fidelity and aesthetics of design in usability tests: Effects on user behaviour, subjective evaluation and emotion. *Applied Ergonomics*. 40, 670–677.

Savelsbergh, G.J.P., Van der Kamp, J., Williams, A.M., Ward, P., 2005. Anticipation and visual search behaviour in expert soccer goalkeepers. *Ergonomics*. 48, 1686–1697.

Savoy, A., Guo, Y., Salvendy, G., 2009. Effects of importance and detectability of usability problems on sample size requirements. *International Journal of Human-Computer Interaction*. 25, 430–440.

Schiffman, H.R., 2001. *Sensation and perception: An integrated approach*. John Wiley & Sons, New York.

Schoelles, M.J., Gray, W.D., 2000. Argus prime: Modeling emergent microstrategies in a complex, simulated task environment. *3rd International Conference on Cognitive Modeling*, Veenendal, NL, Universal Press.

Senders, J.W., Kristofferson, A.B., Levison, W.H., Dietrich, C.W., Ward, J.L., 1967. The attentional demand of automobile driving. *Highway Research Record*. 1967, 15–33.

Seppelt, B., Wickens, C.D., 2003. *In-vehicle tasks: Effects of modality, driving relevance, and redundancy*. Aviation Human Factors Division, University of Illinois, Urbana-Champaign, IL.

Shackel, B., 1959. Ergonomics for a computer. *Design*. 120, 36–39.

Shackel, B., 1986. Ergonomics in design for usability. *2nd Conference of The British Computer Society Human Computer Special Interest Group*, York, September 23–26, 1986, University Press.

Shackel, B., 1997. Human-computer interaction—whence and whither? *Journal of the American Society for Information Science*. 48, 970–986.

Shinar, D., 2008. Looks are (almost) everything: Where drivers look to get information. *Human Factors*. 50, 380–384.

Shneiderman, B., 1992. *Designing the user interface: Strategies for effective human-computer interaction*. Addison-Wesley, New York.

Shneiderman, B., 2000. Universal usability: Pushing human-computer interaction research to empower every citizen. *Communications of the ACM*. 43, 84–91.
Sivak, M., 1996. The information that drivers use: Is it indeed 90% visual? *Perception*. 25, 1081–1089.
Snowden, R., Thompson, P., Troscianko, T., 2006. *Basic vision: An introduction to visual perception*. University Press, Oxford.
Snyder, R.G., Spencer, M.L., Owings, C.L., Schneider, L.W., 1975. *Physical characteristics of children: As related to death and injury for consumer product design and use*. University of Michigan Transportation Research Institute (UMTRI), Ann Arbor, MI.
Society of Automotive Engineers, 2002. SAE J2365 (proposed draft). Calculation of the time to complete in-vehicle navigation and route guidance tasks.
Sodhi, M., Reimer, B., Llamazares, I., 2002. Glance analysis of driver eye movements to evaluate distraction. *Behavior Research Methods Instruments and Computers*. 34, 529–538.
Sonderegger, A., Sauer, J., 2009. The influence of laboratory set-up in usability tests: Effects on user performance, subjective ratings and physiological measures. *Ergonomics*. 52, 1350–1361.
Sperling, G., 1960. The information available in brief visual presentations. *Psychological Monographs: General and Applied*. 74, 1–29.
Stanton, N.A., 1998. Product design with people in mind, in: N. Stanton (ed.). *Human factors in consumer products*. Taylor & Francis, London, pp. 1–17.
Stanton, N.A., 2006. Hierarchical task analysis: Developments, applications, and extensions. *Applied Ergonomics*. 37, 55–79.
Stanton, N.A., Baber, C., 1992. Usability and EC directive 90/270. *Displays*. 13, 151–160.
Stanton, N.A., Baber, C., 2008. Modelling of human alarm handling response times: A case study of the Ladbroke Grove rail accident in the UK. *Ergonomics*. 51, 423–440.
Stanton, N.A., Dunoyer, A., Leatherland, A., 2011. Detection of new in-path targets by drivers using stop and go adaptive cruise control. *Applied Ergonomics*. 42, 592–601.
Stanton, N.A., Salmon, P.M., 2009. Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. *Safety Science*. 47, 227–237.
Stanton, N.A., Salmon, P.M., Walker, G.H., Baber, C., Jenkins, D.P., 2005. *Human factors methods: A practical guide for engineering and design*. Ashgate, Aldershot.
Stanton, N.A., Stevenage, S.V., 1998. Learning to predict human error: Issues of acceptability, reliability and validity. *Ergonomics*. 41, 1737–1756.
Stanton, N.A., Walker, G.H., 2011. Exploring the psychological factors involved in the Ladbroke Grove rail accident. *Accident Analysis and Prevention*. 43, 1117–1127.
Stanton, N.A., Walker, G.H., Young, M.S., Kazi, T., Salmon, P.M., 2007a. Changing drivers' minds: The evaluation of an advanced driver coaching system. *Ergonomics*. 50, 1209–1234.
Stanton, N.A., Young, M., McCaulder, B., 1997. Drive-by-wire: The case of driver workload and reclaiming control with adaptive cruise control. *Safety Science*. 27, 149–159.
Stanton, N.A., Young, M.S., 1998a. Ergonomics methods in consumer product design and evaluation, in: N.A. Stanton (ed.). *Human factors in consumer products*. Taylor & Francis, London, pp. 21–54.
Stanton, N.A., Young, M.S., 1998b. Is utility in the mind of the beholder? A study of ergonomics methods. *Applied Ergonomics*. 29, 41–54.
Stanton, N.A., Young, M.S., 1999a. *A guide to methodology in ergonomics: Designing for human use*. Taylor & Francis, London.
Stanton, N.A., Young, M.S., 1999b. What price ergonomics? *Nature*. 399, 197–198.
Stanton, N.A., Young, M.S., 2003. Giving ergonomics away? The application of ergonomics methods by novices. *Applied Ergonomics*. 34, 479–490.

Stanton, N.A., Young, M.S., Walker, G.H., 2007b. The psychology of driving automation: A discussion with Professor Don Norman. *International Journal of Vehicle Design*. 45, 289–306.

Staunstrup, P., 2012. Mobile systems [Online]. Available from: http://www.ericssonhistory.com/templates/Ericsson/Article.aspx?id=2095&ArticleID=1390&CatID=363&epslanguage=EN. [Accessed 15.05.2012].

Sternberg, S., 1975. Memory scanning: New findings and current controversies. *Quarterly Journal of Experimental Psychology*. 27, 1–32.

Stevens, A., 2012. The future of in-vehicle navigation systems. *ITS International* [Online]. Route One Publishing Ltd. Available from: http://www.itsinternational.com/categories/location-based-systems/features/the-future-of-in-vehicle-navigation-systems/. [Accessed 01.08.2012].

Stevens, A., Board, A., Allen, P., Quimby, A., 1999. A safety checklist for the assessment of in-vehicle information systems: A user's manual. Transport Research Laboratory, London.

Stevens, A., Cynk, S., Beesley, R., 2011. Revision of the checklist for the assessment of in-vehicle information systems. Transport Research Laboratory, London.

Stevens, A., Quimby, A., Board, A., Kersloot, T., Burns, P., 2002. Design guidelines for safety of in-vehicle information systems. Transport Research Laboratory, London.

Strayer, D.L., Drews, F.A., 2007. Multitasking in the automobile, in: A.F. Kramer (ed.). *Attention: From theory to practice*. University Press, Oxford, pp. 121–133.

Summala, H., Nieminen, T., Punto, M., 1996. Maintaining lane position with peripheral vision during in-vehicle tasks. *Human Factors*. 38, 442–451.

Sutter, C., 2007. Sunsumotor transformation of input devices and the impact on practice and task difficulty. *Ergonomics*. 50, 1999–2016.

Sweeney, M., Maguire, M., Shackel, B., 1993. Evaluating user-computer interaction: A framework. *International Journal of Man-Machine Studies*. 38, 689–711.

Taveira, A.D., Choi, S.D., 2009. Review study of computer input devices and older users. *International Journal of Human-Computer Interaction*. 25, 455–474.

Tijerina, L., Parmer, E., Goodman, M.J., 1998. Driver workload assessment of route guidance system destination entry while driving: A test track study. *5th ITS World Congress*, Seoul, October12–16, 1998, ITS.

Tilley, A.R., Henry Dreyfuss Associates, 2002. *The measure of man and woman: Human factors in design*. John Wiley & Sons, New York.

Tingvall, C., Eckstein, L., Hammer, M., 2009. Government and industry perspectives on driver distraction, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 603–618.

Tsimhoni, O., Green, P., 2003. Time-sharing of a visual in-vehicle task while driving: The effects of four key constructs. *2nd International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*, Park City, Utah, July 21–24, 2003, Elsevier.

Tsimonhi, O., Smith, D., Green, P., 2004. Address entry while driving: Speech recognition versus a touch-screen keyboard. *Human Factors*. 46, 600–610.

Tsimhoni, O., Yoo, H., Green, P., 1999. *Effects of visual demand and in-vehicle task complexity on driving and task performance as assessed by visual occlusion*. University of Michigan Transportation Research Instutute (UMTRI), Ann Arbor, MI.

van der Horst, R., 2004. Occlusion as a measure for visual workload: An overview of TNO occlusion research in car driving. *Applied Ergonomics*. 35, 189–196.

Victor, T.W., Engström, J., Harbluck, J.L., 2009. Distraction asessment methods based on visual behaviour and event detection, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects, and mitigation*. CRC Press, Boca Raton, FL, pp. 135–165.

Volkswagen, 2012. Passat saloon: Driver-assistance [Online]. Volkswagen. Available from: http://www.volkswagen.co.uk/#/new/passat-vii/explore/experience/driver-assistance/. [Accessed 06.08.2012].

Walker, G.H., Stanton, N.A., Young, M.S., 2001. Where is computing driving cars? *International Journal of Human-Computer Interaction*. 13, 203–229.

Walter, S., 1986. Letter to the editor: Problems with percentiles. *International Journal of Epidemiology*. 15, 431–432.

Wang, X., Trasbot, J., 2011. Effects of target location, stature and hand grip type on in-vehicle reach discomfort. *Ergonomics*. 54, 466–476.

Wang, Y., Mehler, B., Reimer, B., Lammers, V., D'Ambrosio, L.A., Coughlin, J.F., 2010. The validity of driving simulation for assessing differences between in-vehicle informational interfaces: A comparison with field testing. *Ergonomics*. 53, 404–420.

Whitfield, D., Langford, J., 2001. *The Oxford companion to the body: No. 1*. Oxford University Press, Oxford.

Wickens, C.D., 1991. Processing resources and attention in: D.L. Damos (ed.). *Multiple-task performance*. Taylor & Francis, London, pp. 3–34.

Wickens, C.D., 2002. Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*. 3, 159–177.

Wierwille, W.W., 1993. Visual and manual demands of in car controls and displays, in: B. Peacock and B. Karwowski (eds.). *Automotive ergonomics*. Taylor & Francis, London, UK, pp. 299–313.

Wilkinson, L., 1999. Statistical methods in psychology journals: Guidelines and explanations. *American Psychologist*. 54, 594–604.

Wilson, C.E., 2006. Triangulation: The explicit use of multiple methods, measures, and approaches for determining core issues in product development. *Interactions*. 46–63.

Wilson, J.R., Corlett, N., 2005. *Evaluation of human work*. CRC Press, Boca Raton, FL.

Wittmann, M., Kiss, M., Gugg, P., Steffen, A., Fink, M., Pöppel, E., Kamiya, H., 2006. Effects of display position of a visual in-vehicle task on simulated driving. *Applied Ergonomics*. 37, 187–199.

Wolfe, J.M., 1998. Visual search, in: H. Pashler (ed.). *Attention*. Psychology Press, Hove, pp. 13–73.

Wolfe, J.M., 2007. Guided search 4.0: Current progress with a model of visual search, in: W. Gray (ed.). *Intergrated models of cognitive systems*. Oxford University Press, New York, pp. 99–119.

World Health Organization, 2011. Mobile phone use: A growing problem of driver distraction. WHO, Geneva, Switzerland.

Young, K.L., Lenné, M.G., Williamson, A.R., 2011a. Sensitivity of the lane change test as a measure of in-vehicle system demand. *Applied Ergonomics*. 42, 611–618.

Young, K.L., Regan, M.A., Hammer, M., 2003. Driver distraction: A review of the literature. Monash University Accident Research Centre, Victoria.

Young, K.L., Regan, M.A., Lee, J.D., 2009a. Factors moderating the impact of distraction on driving performance and safety, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 335–351.

Young, K.L., Regan, M.A., Lee, J.D., 2009b. Measuring the effects of driver distraction: Direct driving performance methods and measures, in: M.A. Regan, J.D. Lee and K.L. Young (eds.). *Driver distraction: Theory, effects and mitigation*. CRC Press, Boca Raton, FL, pp. 85–105.

Young, M.S., Birrell, S.A., Stanton, N.A., 2011b. Safe driving in a green world: A review of driver performance benchmarks and technologies to support 'smart' driving. *Applied Ergonomics*. 42, 533–539.

Young, M.S., Mahfoud, J.M., Walker, G.H., Jenkins, D.P., Stanton, N.A., 2008. Crash dieting: The effects of eating and drinking on driving performance. *Accident Analysis and Prevention*. 40, 142–148.

Young, M.S., Stanton, N.A., 2002. Malleable attentional resources theory: A new explanation for the effects of mental underload on performance. *Human Factors*. 44, 365–375.

Young, M.S., Stanton, N.A., 2007. What's skill got to do with it? Vehicle automation and driver mental workload. *Ergonomics*. 50, 1324–1339.